

An Investigation of Speechreading in Profoundly Congenitally Deaf British Adults

Tara Ellis Mohammed

**Department of Human Communication Science
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A thesis submitted for the degree of Doctor of Philosophy

June 2007

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Tara Ellis Mohammed, Dept. of Human Communication Science, UCL

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Abstract

Speechreading is the major route through which deaf people access the spoken language of the society in which they live. This thesis investigated speechreading and its correlates in a group of profoundly congenitally deaf British adults, and in a control group of hearing adults. For this purpose, the Test of Adult Speechreading (TAS) was developed.

The TAS was designed to be sensitive to the perceptual abilities that underlie speechreading at varying linguistic levels, and to be appropriate, therefore, for use with d/Deaf as well as hearing individuals. The vocabulary and syntax used were selected to be familiar to Deaf adults, and the response mode, using picture choices only, made no demands on written or expressive spoken English.

This new test was administered silently to groups of congenitally deaf and hearing adults, with a battery of visual, cognitive and language tasks. The deaf participants differed in their language and educational backgrounds, but all had hearing losses over 90dB. They significantly outperformed the hearing group on the TAS, even when only closely matched pairs of participants were included in the analyses. Adults who are deaf *can* speechread better than those who are hearing.

Multiple factors impact on an individual's speechreading abilities, and no single factor in isolation results in good speechreading skills. In addition to hearing status, other factors were identified through group comparisons, correlation and regression analyses, cluster analyses and multiple case studies, as being potentially necessary (although not sufficient) for skilled speechreading. These were lexical knowledge, the ability to visually identify sentence focus, and verbal working memory capacity. A range of further factors facilitated skilled speechreading, including hearing aid use, the use of speech at home during childhood, sensitivity to visual motion, personality (risk-taking & impulsiveness), and reading age. It seems there are many ways to become a skilled speechreader.

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Chapter 1

INTRODUCTION TO SPEECHREADING

*Sights can the signs of thought supply,
And with a look I hear.*¹

1.1 Introduction

The principal aim of this thesis is to investigate speechreading in profoundly congenitally deaf British adults. To this end, a new speechreading assessment was developed: the Test of Adult Speechreading (TAS). This assessment tool was used to investigate how the speechreading abilities of deaf adults compare with those of hearing adults, and the characteristics and skills that are associated with skilled speechreading.

This chapter forms a background introduction to speechreading. The sections that follow will consider in turn exactly what is meant by the term ‘speechreading’, the role of speechreading for people with normal hearing in audio-visual speech perception, the role of speechreading for people with a hearing loss, and why the continued study of speechreading is important.

1.2 Defining Speechreading

In 1648, on the title page of *Philocophus: or, the Deafe and Dumb Mans Friend*, John Bulwar described a

“subtile Art, which may inable one with an *observant Eie*, to *Heare* what any man speaks by the moving of his lips.”

Many terms have been used to describe that ‘subtile art’ since then. Silverman & Kricos (1990) give the examples labiology, labiomancy, ocular audition, visual communication, visual hearing, visual listening, and visual perception of speech, in addition to the two most commonly used: ‘lipreading’ and ‘speechreading’. Woodward and Barber justified the use of the term ‘lipreading’ because they found that “only labial articulations are discriminated consistently” (Woodward & Barber 1960, pg. 220). However, subsequent research has shown that speechreaders make

¹ From ‘The Deaf Man’s Soliloquy’, James Montgomery (1848)

use of more than lip information (Greenberg & Bode 1968; McGrath 1985; Munhall & Vatikiotis-Bateson 1998; Vatikiotis-Bateson et al. 1994). The visibility of the teeth and tongue is important (Summerfield et al. 1989), and face actions away from the mouth area may also contribute to speech perception (Munhall & Vatikiotis-Bateson 1998; see section 3.4.ii). ‘Speechreading’, the term used most commonly in the literature, is therefore preferable to ‘lipreading’, and will be used throughout this thesis.

The term ‘speechreading’ is not, however, used consistently. It can be defined in two distinct ways, depending on the author’s objective. If the objective is to study ‘pure’ visual speech perception (as it is in the majority of the research), then speechreading is the process of perceiving and understanding spoken language using vision alone. In contrast, residual hearing is not excluded from the definition by those who work with people who have a hearing loss in a clinical setting. They use the term to refer to functional speech perception by individuals with a significant hearing loss through the use of vision and residual hearing.

In this thesis, in common with the majority of research in this field, the term ‘speechreading’ will be used to refer only to the *visual* perception and understanding of speech.

1.3 The role of speechreading for people with normal hearing

Most hearing people are unaware of speechreading, and consider it to be relevant only to people with a hearing loss. People with normal hearing do not need to see a talker in order to understand what is said in clear listening conditions. Accordingly, the acoustic, rather than visual, properties of speech have constituted the major focus of research in speech science. Visual speech is, however, known to be important in spoken communication (e.g. Campbell et al. 1998; Dodd & Campbell 1987; Massaro 1987; Massaro 1998; Summerfield 1992).

1.3.i Speechreading in audio-visual speech perception

“Seeing and hearing are co-workers in the daily contacts which enrich our lives” (Bunger 1952, pg. 1).

Although most hearing people are unaware of speechreading, in situations where the acoustic signal is degraded (e.g. in a noisy crowd) the importance of seeing speech for hearing perceivers becomes evident: the listener finds it easier to understand a speaker’s message while looking at his face. Early studies estimated that seeing the

talker results in a gain in intelligibility equivalent to approximately a 15dB increase in signal-to-noise ratio for English users (Miller & Nicely 1955; Sumby & Pollack 1954); and numerous studies since then have shown that visual speech information dramatically and consistently improves the intelligibility of auditorially perceived speech in quiet and noisy environments (Arnold & Hill 2001; Erber 1969; Helfer & Freyman 2005; MacLeod & Summerfield 1987; MacLeod & Summerfield 1990; Middleweerd & Plomp 1987; Reisberg 1978; Reisberg et al. 1987; Sanders & Goodrich 1971). Reisberg and colleagues (1987) and Arnold and Hill (2001) showed that visual information is also demonstrably used when speech is clearly audible if it has a heavy foreign accent or conveys complicated subject matter. There is also evidence that access to visual speech is necessary for normal speech development (Mills 1987). Blind children are frequently found to have articulatory problems (e.g. LeZac & Starbuck 1964), suggesting that the inability to see the articulations of others (that is, the inability to speechread) has a detrimental affect on learning phonology. Sighted children learn phonemes with visible articulations (e.g. bilabials and labiodentals) more quickly than those that are difficult to see (e.g. glottal and velar phonemes). Blind children, on the other hand, acquire visibly articulated sounds more slowly (Mills 1987).

One of the clearest demonstrations of the importance of the role of vision in speech perception is the ‘McGurk effect’. Thirty years ago, McGurk and MacDonald demonstrated a powerful auditory-visual blend illusion, where a heard “ba” and a synchronously seen “ga” give rise to the impression of a heard “da” (McGurk & MacDonald 1976; see <http://www.haskins.yale.edu/featured/heads/mcgurk.html> for demonstrations). This effect, demonstrating the integration of visual and auditory speech information, is robust and relatively automatic. It has been demonstrated in adults and children, and even in four to five month old infants (Burnham & Dodd 1996).

The ability to obtain visual speech information from the face is robust (Massaro 1999): accuracy is not dramatically reduced when extra-oral portions of the face are missing, nor when it is viewed in non-optimal conditions. Even the loss of temporal synchrony can be tolerated: vision continues to affect audition when the signals are

displaced by 250 ms or more (vision leading²), depending on the task (Grant et al. 2004).

Why does seeing speech help hearing individuals to process it? Visual speech information both complements, and adds to the redundancy of the auditory signal. The complementary nature of the visual and auditory signals arises because vision provides information about some aspects of the speech signal that are difficult to hear, and vice versa. Differences in articulatory place (e.g. /ba/ and /da/) are relatively easy to see on the face, but difficult to hear, and the opposite is true of differences in articulatory manner (e.g. /ba/ and /ma/) (Summerfield 1987). The visual signal may therefore disambiguate the auditory signal. There is also, however, a systematic correlation between the visual and auditory signals, reflecting the underlying dynamics of speech production. The visually perceived movements of a talker's head and face correlate with the auditorially perceived acoustics of the speech signal such that either can be used to partially predict the other (Vatikiotis-Bateson & Yehia 1996; Yehia et al. 1998; Yehia et al. 2002; see section 3.4.i, on 'time-varying information' for further discussion of this work). In addition, visually perceived timing information helps the listener to pick out speech from background noise (Hazan 2001), and visual speech cues provide information about who is speaking³, which enables the listener to tune in to that speaker (see e.g. the impact of visually perceived talker gender on phoneme perception, Green et al. 1991).

1.4 The role of speechreading for people with a hearing loss

“If he that speaks looks towards them, and modifies his organs by distinct and full utterance, they know so well what is spoken, that it is an expression scarcely figurative to say, they hear with the eye” (Johnson 1775, pg. 381)

People with a hearing loss, even successful hearing aid users with moderate losses, rely heavily on visual information (Walden et al. 1990), and comments such as “I can hear much better with my glasses on” and “I don't hear so well in the dark” are common (e.g. Plant 1997). Speechreading is thus very important to these individuals to supplement the acoustic signal.

² Tolerance of vision-led asynchronies is greater than of audition-led asynchronies, this may partially reflect anticipatory co-articulation: the visually perceived movements of the mouth often occur prior to vocalisation.

³ In fact visual information about the source of an auditory signal is so strong that, wherever its actual source, perceivers locate an artificial speech source at the position of a visually perceived apparent talker (the ventriloquism effect, Radeau & Bertelson 1974).

For profoundly deaf people who choose to use speech, speechreading is so important that they probably exploit their hearing aids (if worn) as aids to speechreading rather than as aids to hearing (Rosen & Corcoran 1982). Studies by Erber (1974) and Seewald and colleagues (1985) indicate that the majority of deaf children with a hearing loss of over 90 dB rely primarily on speechreading in the perception of speech.

Speech is not the chosen primary mode of communication for many deaf people (see Chapter 2, Section B), and some express strong negative feelings about speechreading, which they see as an aspect of oralism. However, d/Deaf⁴ people in the UK live in a hearing, speaking world, are surrounded by speech, and have to communicate with non-signing hearing people in many everyday situations (e.g. shopping). British Sign Language (BSL) users also look at each other's faces, not their hands, when communicating (Sutton-Spence & Woll 1999); and there are spoken components in BSL (see Marschark et al. 1998, and section 2.9). The spoken components in the language of hearing or deafened signers, or fluent signers using a register for communicating with speaking people with little sign language, often look like whispered English (Sutton-Spence & Woll 1999). Speechreading therefore plays important roles in the communication of both hearing and deaf people, whatever their preferred language.

1.5 Why study speechreading?

"Knowledge of the phenomenon of lip-reading appears to be a sort of will-o-the-wisp that eludes objective study." (Reid 1946, pg. 412)

Over the last century there has been a large body of research investigating speechreading. It remains an exciting area of research for a number of reasons. From a purely theoretical viewpoint, it adds to our understanding of audiovisual speech perception and processing. It is, for example, important in evaluating models of speech perception for hearing people (see e.g. Massaro 1999). In addition, research into the cognitive processes underlying speechreading in congenitally profoundly deaf

⁴ 'Deaf' with an upper case 'D' is a widely accepted way of denoting cultural deafness and describes people who choose to identify with the Deaf community; 'deaf' with a lower case 'd' is a broader term which can refer to anyone with a hearing loss. Not all people who are deaf choose to be Deaf. Woodward (1972) began this convention of distinguishing functional hearing loss (deaf) from identification with the cultural community (Deaf).

and hearing people may indicate whether the two groups process visual speech in the same way.

There has, historically, been a lot of work focussed on how to predict speechreading proficiency in individuals. Overall this has been unsuccessful in achieving its goal, and no consistent set of speechreading predictors has yet been identified (Bernstein & Auer 1996; Jeffers & Barley 1971). It remains important, however, to understand the correlates and predictors of speechreading skill. Speechreading is the major route for spoken language comprehension in the majority of deaf children who are born to hearing parents. An increasing number of these children are being educated in mainstream schools, but their speechreading skill is highly variable: an improved understanding of the predictors of speechreading skill may inform future foci for intervention. This is particularly important since speechreading has been shown to be strongly correlated with reading in deaf children (e.g. Arnold & Köpsel 1996) and adults (e.g. Bernstein et al. 1998a). Literacy levels are often poor in deaf adults (Paul 2001). An increased understanding of the relationship between reading and speechreading, and of the predictors of speechreading skill, may add to our understanding of why some deaf individuals attain good levels of literacy while many do not, and may inform future literacy teaching methods. In addition, speechreading proficiency has been found to be associated with successful outcome following cochlear implantation (Lyxell et al. 1996; Summerfield & Marshall 1994). As increasing numbers of children and adults are implanted, greater understanding of the predictors of success are vital to inform assessment for implant candidacy, intervention, and education placement.

The predictors of speechreading skill have not emerged from the large body of existing research for at least two reasons. Firstly, much of it has been carried out using assessment materials that were not developed to assess speechreading ability in deaf and hearing people; many were actually developed to assess auditory speech comprehension. The development of the speechreading assessment described within this thesis was driven by a need for suitable assessment materials, and informed by previous research and extant tests (see Chapter 4).

Secondly, the deaf population is particularly heterogeneous (see Chapter 2), and deaf people, many of whom are bilingual in English and British Sign Language, can show marked differences from hearing people in all aspects of spoken language (e.g. Bishop

& Mogford 1993; see Chapter 2, Section E, and Chapter 3). It can be assumed, therefore, that the correlates and predictors of speechreading may differ in these groups. Often, however, important demographic information has been not mentioned, or not controlled for (e.g. the existence of co-morbid disabilities). Further, in reviews (see e.g. Jeffers & Barley 1971), the findings from research with a variety of participants (e.g. hearing, hard-of-hearing, prelingually profoundly deaf, participants with an acquired deafness of varying degrees, or a mixture of these) have been combined in the search for speechreading correlates. That consistent predictors of speechreading have failed to emerge from the plethora of work that has been done in this area reflects, in part, the enormously heterogeneous nature of the participants included in the search. It is important that speechreading research is conducted with carefully specified groups of participants, and that results are interpreted with reference to potentially important demographic characteristics.

1.6 The Current Study

This thesis seeks to explore speechreading, primarily in congenitally profoundly deaf adults. Speechreading in this population is particularly interesting because, due to their extremely diminished and altered auditory input, speechreading provides their only access to the spoken language of the society in which they live. Groups of hearing adults are also included for comparison.

The development of a speechreading assessment is described, and the results of its use in investigations of the relative speechreading skills of groups of deaf and hearing adults, and the correlates of speechreading, are discussed.

The questions addressed include the following:

- What should a test of speechreading in deaf and hearing adults comprise? Is the newly developed Test of Adult Speechreading (TAS) a reliable, valid, discriminatory and sensitive assessment of speechreading in deaf and hearing British adults?
- How do the speechreading abilities of deaf and hearing people compare: is there a convincing difference in speechreading ability as a function of hearing status?
- Are there subgroups of deaf and/or hearing adults with superior speechreading abilities?
- Are aspects of personality associated with speechreading ability for deaf and/or hearing adults?

- Do deaf and hearing groups show different patterns of speechreading performance or ability?
- Can aspects of prosody be speechread?
- Is sensitivity to low-level visual form and/or motion related to speechreading ability in deaf and/or hearing adults?
- Which language-related correlates of speechreading predict individual differences in performance on the TAS?
- Is there a relationship between speechreading and reading for deaf and/or hearing adults, and if so, is it direct or is it mediated by other variables?
- Do the attributes and skills of individual expert speechreaders reflect the associations suggested by group comparisons and correlations?

In order to address these questions, Chapters 2 and 3 initially provide some background on deafness and on speech processing. Chapter 2 describes the heterogeneous nature of the deaf population, the factors that contribute to the differences between the life experiences of deaf and hearing adults, and language development in deaf children.

Chapter 2

INTRODUCTION TO DEAFNESS

2.1 Introduction

A subgroup of the deaf population is considered in this thesis: all of the deaf participants were born severely or profoundly deaf. This is a particularly interesting group to study from a speechreading perspective because they have had minimal experience of speech sounds, and those that they do experience are distorted with respect to normal hearing (see section 2.5). They therefore rely almost entirely on speechreading to access spoken language. The participant group was not, however, selected on the basis of any language-, education- or family-based criteria. The sample population therefore reflects the heterogeneity of congenitally profoundly deaf individuals. The inclusion and consideration of these factors is important in achieving a more realistic understanding of the speechreading abilities of deaf people.

In this chapter, factors that contribute to the heterogeneity of the deaf population, and which contribute to the differences between the life experiences of deaf and hearing adults are outlined in order to:

- Define the terms that are important in research involving deaf participants.
- Account for the inclusion criteria for the deaf participants in this thesis.
- Identify factors likely to affect the speechreading abilities and strategies of the deaf participants in this thesis.

The chapter is arranged in six sections: (A) audiological and aetiological factors, (B) communication mode choices, (C) education, (D) family factors, (E) language development, and (F) hearing people with d/Deaf parents will each be considered in turn.

Section A: Audiological and aetiological factors

From an audiological perspective, even the subgroup of deaf people considered in this thesis is not homogenous. The amount and quality of auditory input differs greatly between deaf people due to the degree of deafness at specific frequencies, the age at the onset of deafness, the cause of the hearing loss, the age at diagnosis of deafness,

the use of hearing aids, and the presence or absence of tinnitus. Each of these audiological and aetiological factors will be discussed below.

2.2 Degree of deafness

Since pure tone audiometry was introduced in the 1930s, it has been possible to measure degree of deafness by testing an individual's responses to tones at different frequencies (250 – 8000 Hz; see section 6.6.ii). An individual's overall degree of hearing loss is usually described as the mean level of hearing loss in decibels in the better ear, and this is the value used as a selection criterion in this thesis.

The overall degree of hearing loss can be used to categorise a person's deafness according to a classification system that ranges from mild to profound. Boundaries of this classification system can vary, but the system recommended by the British Society of Audiology (1988) and endorsed by the British Association of Teachers of the Deaf (shown in Table 2.1) is commonly used in the UK.

Table 2.1: Classification labels of levels of deafness (British Society of Audiology 1988; The British Association of Teachers of the Deaf 2001)

<i>Label</i>	<i>Range of hearing loss</i>
Mild hearing loss	20-40 dB
Moderate hearing loss	41-70 dB
Severe hearing loss	71-95 dB
Profound hearing loss	in excess of 95 dB

To control some of the variability in people's auditory speech experience, only deaf participants with a hearing loss of over 90dB were included in this thesis. A cut-off of 90dB is used commonly in the literature (see e.g. Bernstein et al. 2000): it is the cut-off for profound hearing loss in the USA. Hearing losses over this limit are categorised as severe or profound in the UK (see Table 2.1). The deaf participants included will not have experienced useful auditory speech without amplification (see section 2.5).

2.3 Age at onset of deafness

The age at which a person becomes deaf affects their early auditory speech experience. The age of mastering a language varies from child to child, and the age of

the cut-off for distinguishing prelingually deaf children (who became deaf before learning a spoken language) from postlingually deaf children (who became deaf after learning a spoken language) has varied between studies. For example, Conrad (1979) used a cut-off of 3 years, Miller (2003) used age two, and Bishop (1983), 18 months. However, the experience of sound during these first years of life has an enormous impact on the language development of a child (see e.g. Grant Nicholas & Geers 2006): this period in fact constitutes a sensitive period for language development (NIH 1993). From very early on, hearing and sighted babies seem able to make a link between vision and audition. From birth they turn their heads to search for a sound source (Slater 2000), and young babies link what they hear with what they see (Spelke 1976). This has a specific effect on speechreading development because children who can hear direct their gaze towards a speaking face and can develop some awareness of the congruence between lip and auditory patterns: hearing, sighted infants are sensitive to the synchrony between visual and auditory speech (Dodd 1979). For example, by 4 months (or possibly earlier, see Aldridge et al. 1999) infants recognise the lip patterns that correspond to vowel sounds such as /a/, /i/ and /u/ (Kuhl & Meltzoff 1982; 1984; 1988). By 19 months, hearing children can visually differentiate familiar words (Dodd 1979).

Only *congenitally* deaf people participated in the research reported here. That is, only people with “a hearing impairment that is recognised at birth or that is believed to have been present since birth” (Fortnum et al. 2001, pg. 2). This resolves the issue of the cut off age for prelingual deafness and ensures, as far as possible, that none of the deaf participants had experienced speech sounds as hearing children do.

2.4 Type and aetiology of deafness

There are two main types of deafness:

- *Conductive deafness* is the result of anything (such as a blockage or structural damage) that interferes with the conduction of airborne sound waves to the oval window.
- *Sensorineural deafness* (which used to be called perceptive loss, or nerve loss) is “produced by damage or alteration of the cochlea or the neural structures that lie beyond” (Martin & Clark 2000, pg. 331).

All of the deaf participants included in this study had sensorineural deafness, occurring before or at birth. Table 2.2 shows the causes of sensorineural deafness in

childhood (Watkin 2001), grouped according to the Davis and colleagues' (1997) aetiological classification of the 653 children with permanent hearing impairment (>40dB) born in the Trent region from 1985-1993.

Table 2.2: The causes of sensorineural deafness in childhood (Watkin 2001) and the aetiological classification of the permanently deaf children born in the Trent region from 1985-1993 (Davis et al. 1997)

Aetiology		Examples	%
Congenital	Genetic	Syndromal and non-syndromal	39.7
	Prenatal	Congenital infections (e.g. rubella), maternal illness	3.7
	Cranio-facial abnormalities	Cleft palate, pinna malformations	1.2
Early acquired	Perinatal	Jaundice, ototoxicity, birth asphyxia	6.7
Late acquired	Postnatal	Meningitis, viral meningo-encephalitis (mumps, measles), trauma, ototoxicity, degenerative disease, noise	6.1
Other		Chemotherapy	1.7
Unknown		Unidentified exogenous agent, autosomal recessive (first deaf child), autosomal dominant (new genetic mutation)	40.9

The deaf participants included in this thesis could all be classified into the 'genetic', 'prenatal' or 'unknown' categories Table 2.2. People with a genetic aetiology are less likely to have co-morbid disabilities than the overall deaf population. It is thought that approximately 50% of cases have a genetic cause, even if there does not appear to be a family history of deafness (Davis et al. 1997; Marazita et al. 1993; Watkin 2001; and see Arnos & Pandya 2003). According to Davis and colleagues' study, approximately 40% of children have a known genetic aetiology; this rises to 48% of congenitally deaf children if as many cases as possible in the unknown category are reassigned to an imputed category based on risk factor information. Rather than excluding potential participants whose deafness has non-genetic causes, when the selection criteria already limited the number of possible participants (only approximately 0.001% of children are born profoundly deaf in countries like the United States and the UK, Mencher et al. 1997), participants were screened, and only included if no additional disabilities were reported or apparent. The cause of deafness remains an important factor to take into account, however, especially in comparisons

of deaf people with deaf parents (DoD) and those with hearing parents (DoH), because deafness in DoDs is more likely to have a genetic cause, whereas deafness in DoHs could have a variety of causes. Mild additional disabilities not identified during screening are therefore more likely in the latter group.

2.5 Sensorineural deafness and speech perception

Despite their high mean hearing losses, most severely / profoundly deaf people do not live in a totally silent world: they do experience some sound in their everyday experiences of perceived speech. The use that they are able to make of this sound in facilitating speech perception, however, varies from individual to individual. It can be assumed that the participants who choose to wear hearing aids make conscious use of their available auditory information. However, it is important to note that the auditory speech perception deficits experienced by people with sensorineural deafness cannot be resolved with amplification. All of the deaf participants included in this thesis are therefore dependent on their vision in accessing spoken language.

There is a degree of controversy in the literature about the speech perception difficulties associated with sensorineural hearing loss. Evidence suggests that, for severe to profound hearing losses, poor discrimination of suprathreshold (audible) stimuli is critical, in addition to the difficulties caused by audibility (Moore 1998). This means that, even if speech is amplified so that it is audible, a person with severe-profound sensorineural deafness will have problems in understanding it.

People with cochlear hearing losses find it particularly difficult to perceive speech against background noise: they are less able to take advantage of temporal and spectral ‘dips’ in interfering sound than people with normal hearing, so their speech perception is worse when the background noise is fluctuating, such as that of another single talker, than when it is a steady noise (Peters et al. 1998).

2.6 Age at diagnosis of deafness

The age at which a child’s deafness is diagnosed affects the ease with which his/her family can adjust, and the way in which they approach communication and relate to their child. Recent advances in technology mean that Universal Neonatal Hearing Screening (UNHS) is becoming increasingly available, known the Newborn Hearing Screening Programme (NHSP) in the UK. However, this was not available for any of the adults who are included in this thesis. Their hearing would first have been

assessed between 6 and 18 months using a screening test called the Health Visitor Distraction Test (HVDT) or Infant Distraction Test (IDT). This test is administered by a health visitor and determines whether a child turns to locate sounds made out of his/her field of vision. There are disadvantages with this test (National Deaf Children's Society 2003): the child can use other senses to 'pass' the test, for example the health visitor may be wearing perfume which the child can smell, or the child may see a shadow. In addition, the baby needs to be old enough and strong enough to turn towards the sound made by the health visitor. Recent statistics show that about 50% of the deaf children born each year had not been diagnosed by the time they were eighteen months old using this method of screening (Davis et al. 1997; RNID 2002), and half of these children had still not been diagnosed by the age of three and a half. For the oldest adults included here, these percentages would have been considerably higher, since when they were babies, the distraction test was new and not in general use (it was first described by Ewing & Ewing 1944).

Failure to diagnose deafness until a child is two or three years old (or older) means that reliable identification of the onset and cause of deafness may be difficult. In addition, late diagnosis is likely to result in more difficult parental and family adjustment (Bamford & McSporrán 1993), and vital opportunities are lost: the child's family lose the time that they could have had to consider and make choices about, for example, intervention, communication and education (see Sections B and C, this chapter). They have no reason to adapt their communication behaviour to accommodate their child's deafness during his/her first years (see section 2.15), and no access to intervention. In addition, since hearing aids are not fitted in early childhood, the opportunity for the child to benefit from potentially important early auditory experience is lost (see section 2.7, on hearing aid use).

Late diagnosis can thus exacerbate the effects of a deaf person's impoverished early language experience (Apuzzo & Yoshinaga-Itano 1995; Davis et al. 1997; Robinshaw 1995; Yoshinaga-Itano et al. 1998). It prevents compensatory strategies and measures focussed on improving the child's communication and language skills from being introduced, and can therefore further impair the subsequent cognitive, social, psychological and language development of the individual. Of particular note here are the severe language delays resulting from congenital deafness that could have been improved with early diagnosis and intervention. Children who were early-identified and had intervention that began within their first year of life have been

found to have significantly better vocabularies, general language abilities (including rate of interaction), syntax (as measured by mean length of utterance), and speech intelligibility and phoneme repertoires (Mayne et al. 1998; Ramkalawan & Davis 1992; Yoshinaga-Itano 1999). The effects of late diagnosis can be pervasive: Powers (1998) found that deaf children who were diagnosed after the age of 3 years achieved significantly lower examination results at the age of 16 than those diagnosed before 3 years. The impact of late diagnosis may extend to adult speechreading ability. Participants who were diagnosed late may therefore be expected to perform less well on speechreading tasks.

2.7 Hearing aid use

Despite their degree of hearing loss, some severely and profoundly deaf adults choose to wear hearing aids, and gain some benefit from them (see section 2.5), whilst others discontinue hearing aid use as soon as they leave school (the majority of children had to – and continue to have to – wear aids in school). In addition to amplified auditory information, a hearing aid can provide useful vibrotactile information (Bernstein & Auer 2003): for a person with a profound hearing loss, hearing aids must operate at high output levels that result in mechanical vibration that can be perceived through the skin (Bernstein et al. 1998b). Cholewiak and Collins (1991) showed that frequencies in the range of voice pitch (approximately 70 to 300 Hz) can be perceived by vibrotactile perception, and Boothroyd and Cawkwell (1970; see also Nober 1967), who studied the problem of distinguishing vibrotactile from auditory perception, found that sensation thresholds below 100dB HL for frequencies as high as 1000 and even 2000 Hz might be attributable to detection of mechanical rather than acoustic vibration.

Hearing aids have improved immensely during the lifetimes of the participants involved in this study. Aids, which sixty years ago would have been useless to all severely and profoundly deaf people, are now discrete, resilient, and powerful enough to be useful. An increasing number of deaf people (mostly children) are now receiving cochlear implants. These neuroprostheses, implanted surgically in the inner ear, take the place of a damaged organ of Corti and stimulate the spiral ganglion cells directly. They will not be discussed further here since none of the participants in this study were implanted.

Hearing aid use is important for speechreading, because individuals who wear aids are likely to use them to supplement their speechreading in everyday situations. The degree to which they can do this will vary widely (see section 2.5), but speechreaders for whom amplified auditory stimulus information facilitates visual speech perception are likely to use speechreading more in everyday life, and their skills may therefore benefit from more practice and increased confidence.

Hearing aid use for the deaf participants therefore varies in terms of the individual's choice of whether or not to wear them, the possible benefits of aid use for an individual, and the aids available during participants' lives. All the deaf participants included in this thesis wore hearing aids at school, and they were asked to report on their current use of aids, or on the age at which they stopped wearing them. Information on their aided hearing loss and their use of auditory information was not available or tested. Younger participants may be expected to be more likely to use hearing aids than older participants since better aids have been available throughout their lives.

2.8 Tinnitus

Tinnitus is "the perception of noise in the absence of objective sound generation" (Caffier et al. 2006, pg. 619); it is subjective, that is, perceived only by the person suffering from it, and can be a variety of noises, such as ringing, hissing, buzzing, or humming. The majority of sufferers hear a single tone; others hear a 'noise' sound, or a mixture of sounds.

Davis (2001) reports that over one in three adults in the UK reports some tinnitus, about five percent of those report that their tinnitus lasts for more than five minutes and is moderately or severely annoying. Because tinnitus is subjective, estimates of its prevalence are very susceptible to small changes in the protocol that defines it. However, Vernon (2001) estimates that 3% of the population suffers from severe tinnitus, based on the results of a number of surveys in the United States and England. Prevalence increases with both severity of hearing loss, and age (Davis & Rafaie 2000). About ten percent of the population of people with a hearing loss of 85 dB or more (in the *worse* ear) suffer from bilateral tinnitus, and fifteen percent of this group have unilateral tinnitus.

Tyler (Tyler 1995) describes tinnitus as "one of the most debilitating symptoms that accompanies sensorineural hearing loss" (pg. 25). It can disrupt quality of life and

interfere with sleep, concentration and productivity. Because it interferes with attention, it may be expected to be detrimental to speechreading ability. Attention serves at least 3 functions (all of which are relevant for speechreading): (1) orientation to environmental stimuli, (2) detection of signals for detailed processing, and (3) maintenance of an alert state (Posner & Petersen 1990). Factors that reduce attention may therefore be expected to adversely affect speechreading performance. For example, Lesner & Hardick (1982) investigated the frequency of spontaneous eye-blinks in a speechreading task. They hypothesised that blinking may reduce visual attention, and in support of this, participants achieving higher passage comprehension scores were observed to blink less frequently than those achieving lower scores.

Since there is a possibility that tinnitus could affect speechreading ability, all of the participants in this thesis were asked to report on the presence, and if applicable, the degree of tinnitus experienced. The impact of this variable on speechreading performance will be investigated prior to the main analyses as a potentially exclusionary variable: participants will be excluded if there is evidence that their speechreading ability is adversely affected by tinnitus.

Section B: Choice of Communication Mode

There are two main language options for a deaf individual: sign language and spoken language. These are not always used independently of each other, so a third category, manual support systems, is also included.

The majority of people do not use one communication mode exclusively, but adapt to their communication partner. Most deaf people are therefore bilingual by Grosjean's (1982) definition of bilingualism as the regular use of two or more languages. They may, for example, use British Sign Language (BSL) within the Deaf community, or when communicating with other fluent signers, but almost all will have had some early exposure to spoken English through their parents or school, and may switch to SSE (Sign Supported English), speech, writing, or a mixture of these as appropriate with non-signers or with beginning or less fluent signers. The proficiency with which people can use these communication modes varies considerably, as does the frequency with which they choose to do so.

2.9 Sign Language

Sign languages, such as BSL (British Sign Language) and ASL (American Sign Language), are natural languages used by Deaf communities around the world. They are now recognised as full human languages (Sutton-Spence & Woll 1999), and the British government announced in March 2003 that British Sign Language, which is used by an estimated 50,000 people in the UK, is to be recognised as an official language with the same status as other minority languages such as Welsh. The syntactical structure of BSL is very different to that of English, the spoken language that surrounds it: in BSL, information is conveyed in space using movement of the hands, face and body. In addition to using signs to represent lexical items, fingerspelling, in which 26 different handshapes are used to represent the letters of the alphabet, is also used. Any English word can therefore be spelt on the hands, but in BSL, fingerspelling is mainly restricted to representing proper nouns.

Although the hands are used extensively in BSL, signers actually look at each other's faces, not their hands, when communicating (De Filippo & Lansing 2006; Muir & Richardson 2005; Siple et al. 1978; Sutton-Spence & Woll 1999). There are many mouth patterns that convey grammatical and phonological information in BSL, and these include instances where English mouth patterns are borrowed – although they are not always used as they are in English and may not be recognisable to a non-signing English speaker. Such instances of spoken components in sign frequently serve to identify or establish a sign, for example in proper names, or in distinguishing homonyms (Sutton-Spence & Woll 1999). Sutton-Spence and Day (1997; 2001) analysed a large corpus of signs produced by native signers in a variety of contexts, and found that 69% of signs were accompanied by 'spoken components'⁵, that is by mouth patterns that were derived from spoken English. 17% were accompanied by oral components that carried meaningful information but were not derived from spoken English, and the remaining 14% of signs were accompanied by a neutral, non-meaningful oral component. Signers were found to use a higher percentage of spoken components when they were signing in a formal register than when they were using an informal, story-telling register (77% compared to 47% in Sutton-Spence and Day's corpus). This suggests that "spoken components serve to increase the identification of lexical items" (Sutton-Spence & Day 1997, pg. 13).

⁵ The terms 'spoken component' and 'oral component' were coined by Schermer (1990).

The findings regarding the impact of sign language use on speechreading are mixed. Bernstein and colleagues (1998a) conclude, based on their results and those of Geers and Moog (1989) and Moores and Sweet (1990), that “the evidence suggests that the more accurate deaf adult speechreaders have had little exposure to manual communication either at home or at school during childhood” (pg. 224). Correspondingly, in Britain, Arnold & Köpsel (1996) found that children educated orally scored significantly better than those educated through the medium of British Sign Language (BSL) on the Donaldson Lipreading test (Montgomery 1966, described in Appendix A). The results of a study by Parasnis (1983) with prelingually deaf young adults suggest that the *timing* of exposure to manual communication may affect speechreading performance: those with delayed exposure to signs (6-12 years) performed better than those exposed early to manual communication. Other authors, however, have found no difference in speechreading as a function of communication type (Meadow 1968; Vernon & Koh 1970), or that manual communication was associated with *better* speechreading (Montgomery 1966; Stuckless & Birch 1966). This led Mogford (1987) to conclude that “there appears to be no evidence to support the claim that learning any manual form of communication interferes with lip-reading skills” (pg. 197).

The likely impact of additional variables on the speechreading abilities of the ‘manual’ and ‘oral’ participants in these studies makes drawing conclusions from them difficult. For example, Arnold and Köpsel’s (1996) group using BSL were selected from a special school and may have had additional difficulties, and Geers and Moog’s (1989) high achieving oral participants had an acknowledged advantage over the wider deaf population in family socio-economic status, parental support, age of fitting first hearing aid, and intelligence. Studies reporting no difference or a manual advantage, on the other hand, compared parental hearing status as well as communication mode: their oral participants had hearing parents, and their manual participants, deaf parents. These groups differ systematically in many other areas that may influence communicative competence and speechreading in addition to communication mode (e.g. age at diagnosis and aetiology of deafness, family reaction to diagnosis; see Section D).

2.10 Spoken language

A minority of congenitally, severely-profoundly deaf British people choose to use spoken English as their preferred language in all situations, and many more use speech or Sign Supported English with communicative partners who have little or no knowledge of BSL. People who choose to use spoken English comparatively frequently are likely to have a better knowledge of the English language, including, for example, a larger vocabulary and a better understanding of English syntax. Speechreading is, by definition, dependent on spoken language knowledge: good linguistic skills enable a speechreader to draw on phonotactic, syntactic, semantic and pragmatic cues in decoding a visually presented spoken message. Aspects of spoken language are therefore considered in a number of sections of this thesis (see particularly Chapters 3 and 9). One area, articulation, will be considered further here.

The intelligibility of deaf people's articulation varies enormously, and this has been proposed as an important factor in speechreading. The motor theory of speech perception (see Liberman & Mattingly 1985) states that "speech is perceived by reference to production" (Liberman et al. 1967, pg. 454). According to this theory, articulation is fundamental to all speech perception – including speechreading. Anecdotally, people do appear to refer to their articulation patterns when speechreading: individuals (deaf and hearing) can be seen 'trying out' different possibilities when trying to decode a speechread word. In support of the motor theory, word listening has been found to produce a phoneme specific activation of speech motor centres (Fadiga et al. 2002). Conklin and Subtelny (1980) report relationships between the reception and production of consonants, with a stronger relationship being reported for the more visible consonants. They also report that speech training, which resulted in significantly increased mean articulation scores for their deaf students, also resulted in small but significant increases in audio-visual speechreading scores. These are unlikely to have been due to practice effects because such an increase was not found in their control group. In addition, Desjardins, Rogers and Werker (1997) found that 3- to 5-year-old children who made substitution errors on an articulation test were poorer at speechreading and had a lower degree of visual perception than children who did not make such errors. Further, Siva and colleagues (Siva et al. 1995; Siva 1995) found that severely dysarthric cerebral-palsied adults, who lacked experience in normal speech production, showed less visual influence in

speech perception under certain conditions (that is, with stimuli that produce phoneme cluster illusions such as /abga/) than non-impaired adults.

2.11 Manual Support Systems

Several systems have been devised to support spoken language. Sign Supported English (SSE) is commonly used in the UK. Here, BSL signs are used to ‘support’ the key English words spoken. English word order is retained and single signs used to represent the main content words. SSE can be considered to be an ‘inter-language’, a form that combines elements of both English and BSL, although the relative dominance of each language will vary between individuals (see Woll 1998). ‘Inter-language’ users may be expected to be better speechreaders than BSL users, because they may be expected to have greater knowledge of English morphology and syntax. Their spoken language knowledge (and speechreading skills) would be expected to be poorer, however, than those of people who choose to use spoken English alone.

Another example of a manual support system, which supports speechreading and is discussed in relation to phonological processing in sections 2.21 and 3.8, is cued speech (Cornett 1967). Cued speech is “a mode of communication for visually conveying traditionally spoken languages at the phonemic level” (Leybaert & Alegria 2003, pg. 262). It is not a sign language, and does not use signs from a sign language. In cued speech, hand cues are made near the mouth to complement the lip gestures of speech. This slows the speech rate by about 30% (i.e. from 6 syllables per second to 4 syllables per second; Duchnowski et al. 1998). Each CV syllable spoken is represented simultaneously by a cue made up of two parameters: handshape, representing the consonant, and location around the mouth, representing the vowel. Phonemes that are comparatively easy to identify through speechreading are cued by the same handshape (e.g. /m/, /f/, /t/) or at the same location. Those that have a similar lip pattern, on the other hand, are cued with different handshapes (e.g. /p/, /b/, /m/) or at different locations (e.g. /i/ and /e/). The handshapes and locations used in cued speech are not therefore interpretable by themselves, but the combination of lip gestures and manual cues provides an unambiguous phonological percept that would not be available from either source alone. Although cued speech has been adapted to more than 56 languages and major dialects (Cornett 1994) it has never been in widespread use with deaf children, and is not used in formal education in the UK. It

is therefore rarely used in this country, and was not used by any of the participants in this thesis.

Many factors impact on the language choices of an individual. For example, their parents' hearing status, knowledge, views and abilities, the advice given to them, and the age at which the individual was diagnosed as deaf will have determined the language approach used in an individual's early (and continuing parental) home life (see Section D). Some parents have very strong views about the language approach to be used with their child. Two examples are a Deaf signing family choosing to communicate in BSL with their child because it is their first language, the language of their community, and the language which their child can develop naturally; or a hearing family choosing to communicate only in spoken English, because it is their only language, the language used by mainstream society, and because they want their child to be 'normal'. For many parents, however, the decision is not that simple: they may, for example, want their child to be able to cope in mainstream, English speaking society, but not want to risk focussing on a language which the child may never use proficiently; or they may want their child to learn BSL naturally as their native language, but have no knowledge of BSL themselves, or be concerned that the child will then have difficulty learning to read and write English text. For the parents of the majority of the older deaf participants, whether d/Deaf or hearing, the decision may have been influenced by educational practices at the time (see Section C): the vast majority of schools had strong oral principles, and some asked parents to maintain the school ban on signing at home as well; parents were told authoritatively that this was best for the child.

For all of the deaf participants, the policies of the school(s) chosen for them to attend, their suitability for the individual concerned, and how successful the policies were for that individual will have impacted enormously, not only on their educational achievements, but on their abilities in (or possibly resentment of) the communication mode used.

Section C: Education

The issues surrounding the education of deaf children have been debated since it was first recognised that a deaf child could learn. They are important and politically sensitive issues which are surrounded by extremely strong views and feelings: Lynas

(1994) writes about the arguments and evidence for different approaches in the education of deaf children, “even a brief glance at this fascinating scene gives cause for concern in that it reveals not so much a debate as a partisan war” (pg. vii). Any professional working in the field of deafness needs to be aware of these issues, but this thesis is not concerned with polemics, and the aim here is not to compare the advantages or disadvantages of educational policies or language approaches. It is instead to outline the educational environments in which the deaf participants included in this research spent a large proportion of their childhood. These will have strongly influenced their language skills, their adult language choices, their attitude to speechreading, and potentially their speechreading abilities.

The deaf adults included in this thesis vary in age from 21 to 61 years, and education practice for deaf children has changed considerably during the time that they were in school. These have been influenced by legislative, technological, and attitudinal changes. This section will briefly describe the education changes that took place between the 1940s and 1980s, and the language approaches used in schools.

2.12 Deaf education from the late 1940s to the 1980s

Up until the mid-1970s the predominant form of education for severely or profoundly deaf children was in special schools. In the post-war period, when the oldest participants included in this research entered education, almost all severely and profoundly deaf children were educated in residential special schools for the hearing impaired. The policies in these schools were generally very oral: signing was not excluded completely in all schools, but it was not usually used systematically as a major means of communication. Sign language (or a manual form of language) was generally only used if the child was deemed to have irretrievably failed with spoken language, or surreptitiously by teachers who were disobeying school policy.

In the 1950s, teachers of the deaf could become qualified with a one-year diploma from Manchester University, and only three weeks experience in a hearing school. Robinson (1958) made a number of criticisms of the education of deaf children at the time. He attributed the inadequacies in teaching to an insufficient number of poorly trained teachers, who emphasised good speech without “a complementary emphasis on the importance of giving the child something to say” (pg. 23), to the inappropriate use of hearing aids, to the lack of teaching syllabuses, and to the lack of continuity between successive stages in schooling.

Deaf pupils only began to be educated in settings other than special schools following a change in the law in 1962, which eliminated the clause of the 1945/53 regulations that had excluded severely and profoundly deaf children from receiving special education in ordinary schools. From the mid-1970s onwards an increasing number of deaf children were placed either in Partially Hearing Units (PHUs, now a misleading term, since they accommodate severely and profoundly deaf children as well) attached to a mainstream schools, or full-time in their local mainstream schools, under the supervision of peripatetic teachers of the deaf. This has led to the closure of a number of special schools for the deaf, and this trend is still continuing. Initially the PHUs were integrated very little with the rest of the school, but by the time the younger adults included here were at school, they had become far less segregated: more deaf children were spending more time with their hearing peers in ordinary classrooms. For example, the 22 children, with a mean hearing loss of 96.2dB in the better ear, featured in Braybrook's 1980 film, '1980 – One Hundred Years after Milan', were spending 68% of their time in mainstream classes. The 1981 Education Act, implemented in 1983, further encouraged the integration of deaf children into mainstream schools.

Developments in hearing aid technology (see section 2.7) have also changed the experience of school for deaf children. In the post-war years (when the oldest participants were beginning school), hearing aids were expensive, bulky, and of poor quality; the powerful behind-the-ear hearing aids available to the younger participants at school, on the other hand, were easier to conceal, which reduced the stigma associated with wearing them, and were less likely to get damaged in the rough and tumble of everyday school life, as well as being far superior in terms of the quality of the auditory input that they delivered to the child.

These changes may impact on speechreading: younger deaf adults, who may have had positive experiences with hearing aids in school may be more likely to continue to use them to supplement their speechreading (see section 2.7, regarding the benefits to speechreading expected as a result of hearing aid use). The older participants are likely to have experienced a strictly oral, but segregated education. The younger participants' families would have had more choice in their school placement, and these participants may be more likely to have attended mainstream schools. The language approaches used in schools have also changed over the lifetime of the participants included here. These are discussed in the following section.

2.13 The language approaches used in schools

The language approach used in school has the potential to impact heavily on a deaf individual's linguistic and cognitive development. Like all children, they spend much of their time in the language environment of their school for many years, and it is through the language approach chosen that they must access education. It is, then, not surprising that this has been, and continues to be, such a contentious issue.

In mainstream schools, children are educated through spoken English, with peripatetic support that varies from school to school and according to need. In specialist schools (which could be day, weekly boarding or full boarding schools) two main language approaches were used during the time the participants were in school: oral, and total communication (TC).

2.13.i Oral schools use one or more of several oral approaches to language. These include 'traditional oral' (a traditional oral teacher is quoted as saying "We confine ourselves to articulation entirely. We do not teach a word with meaning except as a reward... Children are incapable of understanding and must not be strained"; Hodgson 1953, pg. 339), 'structured oralism' (which emphasises the use of residual hearing and hearing aids), the 'maternal reflective approach' (van Uden 1977; unstructured conversations between pupil and teacher are written down for the children to 'reflect' on), and 'natural auralism' (which assumes that, with natural language amplified properly and used as a tool to communicate with rather than a skill to be learnt, spoken language will develop 'normally'). These approaches have the shared goal of achieving good spoken language skills by deaf children, and they do not use manual communication methods. With the exception of traditional oralism (which was developed before hearing aids were in use), they all involve maximising the child's use of their residual hearing by paying particular attention to the appropriate use of hearing aids, and as such, are reported to have become significantly more successful as hearing aids have developed (see e.g. Sainsbury 1986).

2.13.ii Total Communication (TC): Schools that adopt a sign language approach do not usually use full BSL because there is a paucity of teachers with appropriate levels of sign proficiency (i.e. deaf teachers or highly trained hearing teachers of the deaf). A minority of the deaf participants included in this thesis were educated using 'Total Communication' (TC), a (partial) manual language approach. This term is used to describe any language approach that uses combinations of manual, oral, aural, and

written components, and was the most commonly used manual language approach (although has now largely been replaced with sign bilingualism⁶). The oral/aural components are usually similar to the structured oral approach, and the most commonly used manual components are Sign Supported English (SSE, see description in section 2.11) and Signed English (SE), an exact manual representation of English using BSL signs supplemented by invented signs and markers to represent the grammatical features of English; these are delivered simultaneously with speech. Because every word is spoken manually coded in SE, communication is rendered artificially slow. Its use is therefore usually restricted to educational situations. Another system of manually coded English is the Paget Gorman Sign System, which was devised by Sir Richard Paget and introduced in the 1950s to be used in the classroom with deaf children. It uses ‘logical’, invented signs to exactly represent English and is, like SE, used in combination with speech and usually restricted to educational situations. Several of the deaf participants included in this thesis reported having been taught this system as a child.

2.13.iii The impact of school type on speechreading: As discussed in section 2.9, the majority of studies which have compared individuals’ speechreading abilities as a function of the communication mode used at school have found those educated orally to outperform those educated through manual communication (e.g. Arnold & Köpsel 1996). This is, however, likely to reflect other factors in addition to (or possibly instead of) communication mode. For example, attendees at special schools may have additional difficulties, or have been enrolled there after having been deemed to have failed in oral education. Powers (2003) briefly reviewed the issue of the relative general superiority of education approaches, and concluded that “there is no clear evidence supporting one particular type of educational approach” (pg. 59). For example, although a number of studies linked mainstream placement with higher achievement for deaf students (Kluwin & Moores 1985; Lynas 1984; Lynas 1986), many of them do not account for background confounding factors which may have influenced placement choice, such as intelligence, degree of hearing loss and ethnicity. When factors like these are taken into account, school placement accounts

⁶ Sign bilingualism is a more recently developed educational language approach. In this context, bilingualism involves the child learning BSL as a first language, and then English, with the emphasis on written English, as a second language. None of the deaf adults included in thesis were educated using this approach.

for only a little of the variance in achievement (Kluwin 1992), and the direction of relationship of this is not known: high achievement might be either a cause or a result of mainstream school placement. Comparing the participants in this study on the basis of their school type may be further confounded by their age, since deaf education has changed rapidly during the lifetime of the older participants (see section 2.12).

Section D: Family factors

Factors such as the hearing status, attitudes and expectations of a deaf person's family impact on their early social, psychological, cognitive, and language development, all of which are likely to affect their later speechreading abilities.

A minority of children (deaf or hearing) have d/Deaf parents. They have been shown to differ in linguistic, cognitive and emotional development from their peers with hearing parents (see sections 2.14 and 2.15 below). Fortnum and Davis (1997) found that 31% of congenitally, permanently hearing impaired children had a family history of deafness (this was based on children born in the Trent region with a hearing loss of over 40dB). The families of such children may be expected to have some knowledge of deafness, even if both parents are hearing. The majority of deaf children, however, are born to hearing families with little or no knowledge of deafness or sign language. As Marschark (1997) points out, the first deaf person that many parents will ever meet is their own child. This is important because a family's reaction to diagnosis, and the decisions they make following this, will depend in part on their level of understanding about deafness.

Parental hearing status may affect the participants' speechreading abilities in a number of ways. Deaf people with deaf and hearing parents (DoD: deaf of deaf, and DoH: deaf of hearing respectively⁷) will be considered separately below.

⁷ These descriptive phrases and their acronyms are used for brevity; see e.g. Mitchell and Karchmer (2004) or Roots (1999) for examples of their use.

2.14 Deaf people with deaf parents (DoD)

Approximately five to ten percent of deaf people have deaf parents (Marschark 1993; Mitchell & Karchmer 2004). This minority of deaf individuals are likely to have been diagnosed early because they are considered to be at risk, and, unlike hearing families for whom diagnosis may come as a shock, the diagnosis may have been expected, and even welcomed. As White (1999) reports:

“While hearing parents struggle with communication and language choice issues, search for answers from professionals, and cope with their own grief reactions to the deafness, Deaf parents are already familiar with the Deaf experience, have social networks of support, and are familiar with educational and community resources for Deaf children. They do not have the prolonged mourning period that hearing parents experience, and are prepared to begin communicating with their Deaf infant in sign language immediately.” (pg. 39-40)

The majority of DoD children grow up in an environment that is socially, culturally, and linguistically different from that of deaf children with hearing parents (e.g. Erting 1994; Morford & Mayberry 2000). The first language in most deaf households in Britain is British Sign Language (BSL, see section 2.9 for a description). The majority of DoDs are therefore able to oversee signed conversations from birth in the same way that hearing children can overhear spoken conversations, and to learn language through modelling in the home (LaSasso & Metzger 1998). Interestingly, many deaf mothers also vocalise to their deaf infants, even though neither can hear the sound (Woll & Kyle 1989), and the BSL used by deaf parents with their deaf children includes a high proportion of spoken components (Sutton-Spence & Day 1997).

Even in homes where the first language is not signed, DoDs are likely to experience a more effective language environment than deaf people with hearing parents (DoH) because deaf parents are usually more aware of their deaf child's communication needs and can more easily accommodate them. They are less likely to unintentionally exclude their child from everyday conversation or activities (such as watching television), and are fully aware of ways to maximise visual communication. They may, for example, be especially responsive to the tactile needs of their deaf infants: deaf mothers have been found to use a greater intensity of touch than hearing mothers (Koester et al. 2000). Deaf signing mothers (and fathers, Loots & Devisé 2003) use a

number of strategies to enable their children to see what they are signing: they may use a 'tap/sign' strategy, briefly tapping the infant's body (usually the arms or legs) before signing, as if to alert the baby to the forthcoming communication (Waxman & Spencer 1997). They are more likely to facilitate their young child's vocabulary learning by displacing their signs, either onto the child (e.g. signing CAT on the child's own face), or into the child's visual field so that the linguistic symbol can be related simultaneously to the referent (Erting et al. 1990; Harris 2001; Harris et al. 1989). They also use a lot of positive affect (in comparison to hearing mothers) (Erting et al. 1990), and are more successful in presenting signed utterances with a salient context (Harris 2001) when communicating with their children. Deaf mothers' use of visual and tactile attention-directing signals results in an increase in their infants' joint attention, such that deaf infants with deaf mothers show significantly longer times in a co-ordinated joint state of attention (the most advanced attention state) than those with hearing mothers (Spencer 2000). In addition, deaf mothers wait until their child is looking at them before starting their interaction (Erting et al. 1990; Harris et al. 1989), and infants with deaf mothers spend more time watching their mothers than those with hearing mothers. This has been attributed to the richness of the visual communication environment provided by deaf, signing mothers (Spencer 2000).

DoDs' rich early language exposure (usually presumed to be sign language) has been credited with resulting in their higher levels of achievement than DoHs (see e.g. Paul 2001): they show superior performance when compared to DoHs on assessments of cognitive ability, such as IQ (Braden 1994) and reading (Kusche et al. 1983). However, they are also less likely to have additional disabilities resulting from the cause of their deafness (Jensema & Mullins 1974), and are likely to have experienced better family dynamics, parental support and general early socialisation than DoHs. For example, deaf parents may be members of the Deaf community, and can therefore introduce their child to Deaf culture and many adult d/Deaf role models. These factors may have contributed to findings that deaf college students with at least one deaf parent had significantly higher self-esteem scores than those with hearing parents (whether or not the hearing parents could sign) (Bat-Chava 1993; Bat-Chava 1994; Crowe 2003).

2.15 Deaf people with hearing parents (DoH)

The majority (approximately 90-95%) of deaf children are born to hearing parents who are unlikely to have previous experience of deaf people. Their knowledge about hearing and the audiological aspects of deafness is likely to be limited, and they may have no knowledge of the Deaf community and their language (BSL). The dynamics of such a family are likely to be drastically changed when a deaf child is born and diagnosed (see Gregory 1976; Gregory et al. 1995). Factors such as marital stability, social support, socio-economic status and mother's educational level all affect a family's adjustment to the diagnosis of a deaf child (see Calderon & Greenberg 1993; Musselman & Kircaali-Iftar 1996).

Hearing mothers face a number of difficulties in managing the attention of their children and meeting the demands of a visual language (see Harris 2000). For example, contingent responding, techniques for making sign available, and the incremental adaptation of language input to reflect the child's growing linguistic maturity may be problematic in hearing mother–deaf child dyads. Synchrony and reciprocity, the hallmarks of effective interaction, may not emerge without support (e.g. through the explicit teaching of communication strategies or through deaf role models) (Vaccari & Marschark 1997). However, hearing mothers have been shown to make some intuitive adaptations to their interactive style to meet their deaf infant's needs, despite their lack of experience with or knowledge about deafness. For example, they increase their use of visual activities and multimodal games (involving vocal plus tactile, visual or kinaesthetic components), use highly animated facial expressions, and incorporate more active forms of tactile contact in their interactions (Koester et al. 2000; Koester 1995; Koester et al. 1998). These intuitive strategies support the development of communication skills by eliciting and maintaining visual attention. They may be important in speechreading development, because, for example, animated expressions encourage the deaf child to focus on their communicating mother's face, and multimodal games may help to reinforce the communicative gestures of speech. Such adaptive behaviour highlights the importance of early diagnosis of deafness (see section 2.6), because parents cannot adapt to needs that they do not know about.

Only a small proportion of hearing parents of deaf children use BSL, and of those that do, few achieve proficiency in its use (Young 1997) because they are late learners of a second language. In practice, therefore, hearing parents often use Sign Supported

English (SSE), an ‘inter-language’ that combines elements of both English and BSL (see section 2.11). Deaf children exposed to such approaches as their principal language input do not receive a good model for either language: the BSL lexical items are not syntactically connected, so the sign language model is ill formed, and the spoken language is likely to be slowed, disjointed, and possibly limited by the adult’s BSL vocabulary.

Outside of the parent–child dyad, deaf children in hearing families are not surrounded by a language they can naturally acquire in the way that hearing children in fluent language environments (spoken or signed) or deaf children in fluent sign language environments are (Crowe 2003). While hearing children are “bathed in verbal language” (Denmark 1994, pg. 5), DoH children may have little experience, auditorially or visually, of overhearing conversations between others. They are therefore not exposed to the majority of the everyday incidental language of their family. Even in families where one or both of the parents are learning BSL, family members are unlikely to sign when not communicating directly with the deaf child. As Ratner (1993) points out, “we probably underestimate the degree to which we gain important linguistic insight from language interchanges that occur around us” (pg. 328). The majority of deaf children thus miss out on an enormous amount of language input and opportunities for vicarious learning during their first few years of life. These years are critical for normal, complete language development. The length of the sensitive period for language development may vary between individuals, but the ability to acquire a first language diminishes with age, and the first three years of life are generally regarded as “the most important period for language and speech development” (NIH 1993). Research conducted by Newport (1990) suggests that the proficient development of sign language is dependent on children’s early exposure to it. The limited language experience and proficiency of the majority of deaf children impacts on virtually every aspect of their life, including their family and other social relationships, literacy development, and educational and employment opportunities and attainments.

In summary, the DoH and DoD participants each have relative speechreading advantages: the former will have grown up surrounded by spoken language in the home, and may have had a stronger motivation to communicate through speech. The DoD participants, on the other hand, are likely to have been diagnosed earlier, to have

benefited from better communication strategies in their early childhood, and to have developed better visual attention skills.

Section E: Speech and Language Development

“An absence of early exposure to the patterns that are inherent in natural language – whether signed or spoken – produces life-long changes in the ability to learn language” (Kuhl 2004, pg. 381).

This section explores the impact that a congenital profound hearing loss has on speech and language development in the majority of deaf children who do not have access to fluent signed language as they are growing up, and the likely consequences for their adult speech processing abilities. Following this, the impact on spoken language development of having BSL as a first language will be considered.

2.16 Early speech perception

Auditory perception has an enormous influence on speech perception in the first year of life. Young hearing infants (under 6 months of age) are able to discriminate between the phonetic contrasts in consonant-vowel syllables from any spoken language, including non-native contrasts (e.g. Iverson & Kuhl 1995; Streeter 1976; Trehub 1976; Werker et al. 1981). Between 6 and 12 months of age, a language-specific shift in phonetic perception occurs (e.g. Best et al. 1995; Best & McRoberts 2003; Kuhl 2004; Werker & Tees 1984). After this age, children’s phonetic perception is constrained such that they are particularly sensitive to the regularities in sound structure that characterise their native language: older children and adults are not able to discriminate between phones that are not contrastive in their native language. The regularities in the sound structure of a language “are important in determining how sounds can be combined to make possible words in the language, in distinguishing among different words, and in specifying boundaries between different words” (Jusczyk 1993, pg. 28).

In addition, hearing infants direct their gaze towards a speaking face and have an awareness of the congruence between lip and auditory patterns: babies have been found to prefer to look at a face speaking if the auditory signal matches the visual signal. At 2½ to 5 months, infants fixate a talker for longer when their lip movements and voice are matched than when they are mismatched (Burnham & Dodd 1998; Dodd 1979). Auditory–visual vowel matching ability has been found for 2-month-old

infants (Patterson & Werker 2003), and there is also some evidence for auditory–visual matching in newborns at 4 to 33 hours old (Aldridge et al. 1999). 18- to 20-week-old infants match auditory presentations with the appropriate lip movements for native vowels (Kuhl & Meltzoff 1982; 1984; 1988) and possibly also for non-native vowels (Walton & Bower 1993b), and 6-month-olds do so for syllables (MacKain et al. 1983). In addition, hearing infants aged 4-5 months have been shown to be sensitive to the McGurk effect (this auditory-visual perceptual illusion is described in Chapter 1, pg. 29) (Burnham & Dodd 2004; Desjardins & Werker 2004; Rosenblum et al. 1997). Hearing infants, then, are sensitive to the audio-visual patterns of speech: auditory information facilitates infants’ visual attention, which may be expected to benefit their visual speech perception. However, that hearing infants integrate visual and auditory information from a very early age also indicates that they do not need to rely on visual information: with regards to speech perception, it is always perceived with the auditory speech signal.

Children who are profoundly deaf from birth, on the other hand, have minimal access to the sound structure of the spoken language that surrounds them. While hearing infants are particularly sensitive to the sounds of their language in the first few months of life, infants with hearing losses are particularly sensitive to visual input and touch (Jusczyk 1997). They cannot become aware of all of the phonology and phonotactic regularities of spoken language through audition. This depresses their production of speech sounds (see section 2.21), and is also likely to impede their ability to segment the stream of speech that they perceive, since phonotactic and allophonic cues (in addition to prosodic stress cues) have been found to be used by infants in speech segmentation (Johnson & Jusczyk 2001; Jusczyk et al. 1999; Mattys et al. 1999, see section 3.2). This in turn further impairs their ability to access and learn spoken vocabulary (see section 2.20).

Deaf infants, then, may be at an early disadvantage in comparison to hearing children in terms of developing speechreading skills. Hearing infants can learn to attribute meaning to face movements through awareness of the congruence of the visual and auditory speech signals. Profoundly deaf children, on the other hand, will have greater difficulty matching the minimal and degraded acoustic signals available to them to meanings and/or to the speech movements that they see. As the children grow up, however, this potential speechreading advantage for those with normal

hearing may be lost, as they come to rely less on seen speech signals, while their deaf contemporaries are dependent on them to access spoken language.

2.17 Babbling

Babbling is a crucial phase in spoken language development: it is a necessary precursor of speech production, and there is a clear continuity between the pre-lexical and lexical stages. In reviewing measures of pre-linguistic development, Stoel-Gammon (1992) found consonant use in pre-linguistic vocalizations to be the most useful predictor of the onset of speech (Menyuk et al. 1986; Stoel-Gammon 1989) and of longer-term phonological outcomes (Vihman & Greenlea 1987; Whitehurst et al. 1991). The delay that is apparent in profoundly deaf children's babbling is a first indication of a developmental pattern that is characteristic of their spoken language development.

Deaf infants begin babbling in much the same way as their hearing peers in their first six months of life, with only isolated exceptions (e.g. 'glottal sequences', have been reported to occur more frequently in deaf than in hearing infants' vocalisations; Koopmans-van Beinum et al. 2001; Oller et al. 1985; Oller 1991; Stoel-Gammon & Otomo 1986). Both groups squeal and growl, whisper and yell, and produce raspberries and many vowel-like sounds (Oller 2006). However, hearing children progress to producing well-formed syllabic combinations ('canonical babble') at around 7 or 8 months (Kuhl 2004). Their caregivers then begin to perceive intentional communication and respond with reinforcement, encouraging children to form their first words and leading to changes in the patterns of adult-child interaction. Profoundly deaf infants, on the other hand, rarely begin producing consistent canonical babbling until well into their second year of life (Eilers & Oller 1994; Koopmans-van Beinum et al. 2001; Oller & Eilers 1988; Stoel-Gammon & Otomo 1986; Vinter 1994a; 1994b).

Deaf children's limited babble, which sounds less like their environmental language than that of hearing children, impacts on the interaction between hearing mothers and their deaf infants. Mothers have been reported to ignore their deaf children's utterances whilst mothers of hearing children integrated utterances into dialogue (Mogford & Gregory 1982). Deaf children may therefore lack early experience of vocal turn taking which impacts negatively on their early pragmatic development, and on early child-caregiver interaction.

2.18 Early Interaction

The spoken language used by hearing mothers with deaf children has been reported to differ from that used with hearing children in a number of ways: they have been found to use more imperatives and fewer declaratives, give less verbal praise, and take less account taken of the child's contribution (Goss 1970; Gregory et al. 1979). In addition, their language has been described as inflexible and repetitious, controlling, intrusive and disapproving (Cheskin 1981; Cheskin 1982; Schlesinger & Meadow 1972). These behaviours seem to be counterproductive for the development of language. However, whilst accepting that “interaction between hearing mothers and their deaf children is likely to proceed less smoothly than in the hearing situation” (pg. 200), Gallaway and Woll (1994) suggest that the findings have been too easily interpreted as suggesting that the interactions are inadequate or inappropriate for facilitating language development. A number of studies (Cross et al. 1980; Gallaway et al. 1990; Hughes 1983; Nienhuys et al. 1984; Power et al. 1990) have found that the simple maternal language used with deaf children is similar to that used with younger hearing children at a similar linguistic level. It could be, therefore, that mothers are adjusting to their child's language level, and this may be supportive rather than unfacilitative, resulting in a reduced processing load for the deaf child. Nonetheless, the interaction experienced by children with profound hearing losses is limited in comparison to that experienced by hearing children.

2.19 From babbling to first words

The phonetic knowledge and skill acquired during the babbling stage facilitates the transition to using language (Stoel-Gammon 1998a; Stoel-Gammon 1998b; Vihman 1996). Vihman and colleagues, among others, have demonstrated that the phonetic parameters characterising early words are also characteristic of prior and contemporaneous babble (Oller et al. 1976; Stoel-Gammon & Cooper 1984; Vihman et al. 1985). The accepted view is now one of continuity between babble and first words (McCune & Vihman 2001; see e.g. Vihman et al. 1985), with hearing children typically beginning this transition with their first word at around twelve months (Fenson et al. 1994; Gesell 1940; Menyuk 1971).

The transition from pre-linguistic to linguistic utterances is predictably delayed in deaf children. The limited perceptual speech information available to them impedes the development of representations linking their perceptual understandings to real-

world object and event references. Their potentially limited social experiences (see section 2.23) and near absence of auditory experience also limit their opportunities to gain pragmatic insight into the communicative potential of sound-meaning correspondences. They therefore miss out on “a critical impetus for active engagement in the verbal expression of meaning” (McCune & Vihman 2001, pg. 682). In addition, deaf children’s delayed and limited babbling skills mean that their vocal motor control is likely to be poor in comparison to their hearing peers. Their late transition to canonical babbling may result in a paucity of consonantal gestures to organise into phonological representations.

Despite these difficulties, profoundly deaf children, and even acochlear (totally deaf) children (Lynch et al. 1989), do develop canonical babbling and linguistic utterances. Auditory input is not, then, the sole trigger for the maturation of vocalisations: visual, proprioceptive, and kinetic information are also important, and can support some articulatory development for speaking in the absence of auditory information. The role of non-auditory information in the transition to linguistic vocalisations factors can be illustrated by considering the role of bilabials (/p/, /b/).

As expected, given the greater visual component of labial consonants, deaf children have been found to produce a higher percentage of them than hearing children, at the expense of alveolar consonants (e.g. /t/, /d/) (van Beinum & Doppen 2003). Labial consonants may, however, have a special role in the transition from pre-linguistic to linguistic utterances for hearing children as well (McCune & Vihman 2001): they occur frequently in early words (Bleile et al. 1993; de Boysson-Bardies & Vihman 1991; Rescorla & Bernstein-Ratner 1996; Stoel-Gammon 1998a; Stoel-Gammon & Cooper 1984; Thal et al. 1995), and may be associated with a spurt in vocabulary (Roberts 1998). McCune & Vihman (2001) attribute this apparent special role for bilabials to visual and proprioceptive cues, and to motoric factors. It is easy for infants to see how to produce bilabials, and this visual information is highly salient for them, given their early attraction to faces (Fantz 1961) and their ability to match speech sounds to mouth movements well before they are begin to produce supraglottal consonants (e.g. Kuhl & Meltzoff 1982; 1984; 1988; see section 2.16). The visual salience of bilabials may cue the child to attempt to produce words that include these consonants. Their likelihood of success is increased by the motoric simplicity of bilabial production: it requires only the mandibular movement that underlies any CV production, but no shift in tongue placement for vowel production. Proprioceptive

cues further increase the child's likelihood of a successful bilabial production, since afferent feedback is transmitted to the sensory cortical representation directly from the cutaneous contact of the lips (Evarts 1982), rather than depending on the complex integration of information from the responses of muscle spindles and golgi tendon organs, which are absent from the lips (Barlowe & Farley 1989). Bilabial gestures are, then, highly accessible, and this may facilitate their use in the cognitively and neurologically complex process of early word production. The non-auditory factors that make labials so accessible are available to both deaf and hearing children, and are fundamental to the development of spoken language in deaf children.

2.20 Vocabulary development

Unsurprisingly, given their babbling development discussed above, deaf children's early vocabulary development is frequently delayed. Hearing children acquire their first words at around 12 months of age, and then reach ten words in about a month (Thatcher 1976). By eighteen to twenty months they generally have around fifty words in their vocabulary, and further vocabulary growth is rapid. In contrast, although some deaf children in spoken language environments acquire their first words at a similar age to hearing children, they typically fall progressively behind their hearing peers (Blamey 2003; Boothroyd et al. 1991; Spencer & Lederberg 1997). Profoundly deaf children may not have acquired ten words by the time they are four years old (see e.g. Gregory & Mogford 1981), and by 8 to 12 years their average comprehension of spoken vocabulary is less than that expected of a 4 year old hearing child (Bishop 1983; MacKay-Soroka & Trehub 1988; Moeller et al. 1986).

By two years of age, most hearing children use two-word utterances frequently in their speech (Wells 1985). Research on the timing of first word combinations has found that it is related to several developmental factors, including the size of children's lexicons, and the responsiveness of mothers to their children's earlier communications (Tamis-LeMonda et al. 1998). In line with their impoverished vocabulary, and the often limited early interaction of hearing mothers with their deaf infants (see section 2.15), deaf children are typically severely delayed in beginning to combine words (Easterbrooks & Baker 2002; Gregory & Mogford 1981; Lederberg & Everhart 2000).

The content of the early lexicons (<35 items) of deaf and hearing children are very similar. They tend to contain words / signs that can assist the child to bring about

change by causing others to act (e.g. milk, no, mummy, ball, cat) (Anderson & Reilly 2002; Easterbrooks & Baker 2002; Gregory & Mogford 1981; Griswold & Commings 1974). However, there has been the suggestion that “while the language of a hearing child arises out of interactive dialogue, that of a hearing-impaired child tends to be taught” (Bamford & Saunders 1991, pg.158). As a result deaf children tend to use comparatively more social words such as “thank-you” and “bye bye” and comparatively fewer nominals (Gregory & Mogford 1981). Curtiss and colleagues (1979) also found labelling to be delayed in young deaf children, but that their ability to indicate locations developed early. This may indicate that deaf infants rely to a greater extent on the visual spatial aspects of their communicative environment.

Incidental learning of vocabulary (e.g. by listening to conversation) accounts for a large proportion of first language vocabulary growth in children (Nagy et al. 1985), but deaf children with hearing parents typically “have no undistorted access to the flow of language and information in the environment” (Vees & Douglas 1995, pg. 1127). In addition, their families often develop routines and conventions that make it easy to communicate without using formal language (Barker 2003). When formal spoken language is used, “hearing people, especially parents, who live with deaf children often ‘dumb down’ their language to make themselves more easily understood, ... [using] fewer idioms, adjectives, and synonyms” (Roffe 1998, pg. 24). Deaf children are therefore exposed to a much reduced variety and complexity of language, even before the amount they are able to perceive is taken into account.

2.20.i Implications of depressed vocabulary development

“Learning, as a language-based activity, is fundamentally and profoundly dependent on vocabulary knowledge” (Baker et al. 1995)

The facets of language development are interrelated. Predictably, deaf children’s slow, restricted vocabulary development impacts directly on their subsequent language development. A reduced vocabulary size therefore affects visual (and audiovisual) spoken language processing beyond the obvious corollary that a word cannot be understood through speechreading if that word is not in the individual’s lexicon. For example, as a child’s productive vocabulary increases, more phonemic categories are required to maintain the phonetic distinctions between new and already known words. The boundaries of phonemic categories and phonotactic sensitivities are thus related to vocabulary size. Hearing children become aware of language-

specific phonotactic and allophonic rules through exposure to that language (Friederici & Wessels 1993; Hohne & Jusczyk 1994; Jusczyk et al. 1993; Jusczyk et al. 1994). Knowledge of these rules facilitates segmentation of the speech stream (see section 3.2.iv), which facilitates further vocabulary learning. Deaf children's limited exposure to spoken language inhibits this facilitative process. They are, instead, likely to be dependent on their lexical representations to build knowledge of the phonotactics of the language.

2.21 Phonology

The phonemes produced by both deaf and hearing children tend to be acquired in a reasonably consistent order (see Blamey 2003). The differences in the productive phonological development of deaf children, however, provide clues about their perceptual abilities. For example, Dodd (1976) found evidence of the influence of speechread information in the phonological processes⁸ displayed by 9- to 12-year-old deaf children. When reducing velar clusters (/kl, kr, gl, gr/), for instance, deaf children tended to delete the plosive, which is difficult to speechread (e.g. pronouncing 'clock' as "lock"), rather than deleting the approximant as hearing children usually do (e.g. pronouncing 'clock' as "cock").

The order of phoneme acquisition is thought to be determined by linguistic (e.g. frequency of occurrence), acoustic (e.g. relative intensity), and articulatory (e.g. place of articulation) factors (Crystal 1981). Linguistic factors are likely to be more important in phoneme development than sensory factors for both deaf and hearing children (Blamey 2003), however, the visibility of phoneme features may have a stronger influence on the order of phoneme development for deaf than for hearing children. Accordingly, the more visible front consonants, such as /b, p, m/, occur earlier in their speech (Smith 1975; Tobey et al. 1994). High visibility is not, however, enough to counteract the difficulty associated with some front consonants, such as the fricatives /f, v, θ/. These low intensity, high frequency, comparatively motorically difficult to produce sounds occur late, if at all, in deaf children's speech. Sounds such as high frequency sibilants (e.g. /s/) and less visible phonemes are often omitted, as are sounds at the ends of words and those embedded in consonant clusters.

⁸ Systematic, rule-governed phonological changes affecting sequences or classes of sounds, e.g. weak syllable deletion, cluster reduction, or reduplication. They are a common and predictable part of normal phonological development (see e.g. Hua & Dodd 2006).

‘Phonological awareness’⁹ does not develop to the same degree in deaf children as in those who are hearing. Deaf individuals have, however, been shown to be able to perform phonological awareness tasks at an above chance level (Campbell & Wright 1988; Dyer et al. 2003; Hanson & Fowler 1987; Hanson & MacGarr 1989; Miller 1997). In addition, they show evidence of using speechread information to perform phonological awareness tasks (Dodd & Hermelin 1977), suggesting that their phonological code was primarily derived through speechreading (Dodd 1987; see section 3.8, for further discussion of the nature of phonological coding in deaf people).

Work by Leybaert and colleagues on cued speech (see description in section 2.11) suggests that there is a critical period for the development of fully specified phonological representations. The efficiency of cued speech has been found to be more pronounced in children exposed to it at home from an early age than in children who experience it only at school later in their childhood (Alegria et al. 1999; Charlier & Leybaert 2000; Leybaert 2000). For example, children exposed consistently to cued speech from early childhood (before the age of three years) were found to show phonological similarity effects and word length effects in their recall performance like their hearing age-matched peers. Children who were exposed to cued speech only at school after the age of six did not show these effects (Leybaert & Charlier 1996).

2.22 Syntax

Deaf children’s incomplete language model results in difficulties with multiword acquisition and slow growth of syntactic abilities. By school age, as a group, deaf children with hearing parents display significant language deficits, and have difficulties with English syntactic structures as well as limited vocabularies (Spencer & Lederberg 1997, pg. 204). Some children, even those with a profound hearing loss, show age-appropriate language skills, but the majority show a delay (Blamey 2003) and (arguably, see e.g. Woll 1998) deviance.

In a study of 150 deaf children aged 4 to 20 years, Moeller and colleagues (1986) found grammatical comprehension to be more delayed than vocabulary comprehension. Few of the students tested achieved grammatical comprehension scores higher than would be expected for hearing 5- to 7-year-olds. This is largely a

⁹ Usually defined as a person’s “awareness of and access to” the phonology of their language (Burgess 2002, pg. 709)

result of deaf children's limited vocabularies (see section 2.20). In addition, their limited incidental or conversational experience with English syntax rules often contributes to an incorrect understanding of them. Typically, only a limited number of syntactic structures are taught in school, often in isolation, which does not provide children with enough experience to learn all the ways they can be used (Wilbur 2000). Deaf children's language has been found to deviate from the normal developmental pattern in a number of ways. For example, it has been suggested that deaf children learn the same syntactic rules as hearing children, but in a different sequence (Pressnell 1973). This may be due to differences in the relative perceptual salience of morphological endings for children who are hearing and those who are deaf. Deaf children may also make errors that are similar in type to those of hearing children, but further-reaching in terms of the impact they have on their language: "what differentiates deaf children's use of over-generalization from hearing children's is its long-term persistence and its extension to larger syntactic domains" (Wilbur 2000, pg. 84).

Much of the research into deaf children's syntactical development has been restricted to written language because of the methodological difficulties associated with transcribing and glossing the language produced by deaf participants (Mogford 1993). Deaf individuals' written language has been found to contain a high proportion of content words (nouns and verbs), but few function words (e.g. conjunctions, auxiliary verbs, prepositions) (Myklebust 1960; Simmons 1962; Volterra et al. 2001). Function words convey little meaning in their own right. To the extent that semantic content plays a role in lexical retrieval, therefore, they are at a disadvantage. This is offset, in part, by their high frequency of occurrence for hearing speakers. However, they tend to be short words, produced rapidly with low stress in fluent everyday speech, and therefore difficult for deaf people to perceive and encode. This may result in function words being perceived with low frequency, and, coupled with their low semantic content, may explain the difficulty deaf users of spoken language experience with them.

The expressive language of individuals who are deaf has also been found to lack flexibility and has been described as stereotyped and repetitious. Simmons (1962), writing at around the time that many of the participants in the current research were in school, reported that taught phrases were used repeatedly and certain word orders rigidly adhered to. The over-use of simple active declarative structures (subject-verb-

object, SVO) was noted, whereas conjoined and complex sentences were found to be infrequent. Quigley and colleagues (1977) also noted, amongst his group of 450 deaf children aged 10 to 18 years, that there was a tendency to impose a subject-verb-object pattern on all sentences. Passive sentences such as ‘The boy was pushed by the girl’ were therefore misunderstood as ‘The boy pushed the girl’. Similarly, the deaf children showed a tendency to connect the nearest noun and verb phrases, and therefore misunderstood sentences such as those containing embedded clauses: ‘The boy who kissed the girl ran away’ would be misunderstood as ‘The boy kissed the girl. The girl ran away’. They suggested therefore that students who are deaf are dependent on the linear order of words, and that they are often not able to deal adequately with the hierarchical structures of English.

All of these findings highlight the importance of speechreading assessment materials above the level of the single word being constructed carefully with the likely language level of deaf speechreaders in mind. They should consist of simple (SVO) English, and not, for example, contain passive sentences or embedded clauses if they are to assess the speechreading of language that the tester is confident would be understood by both deaf and hearing speechreaders.

2.23 Pragmatics

Hearing children begin to acquire pragmatic language skills in infancy, and reach conversational maturity at around ten years of age. The early development of conversational turn-taking skills occurs through children’s interaction with their primary caregivers. In deaf children, this is disrupted by their limited babbling skills (see section 2.17). Deaf children experience a reduced quantity and quality of interactional experiences (Clark 1989; Gallaway & Woll 1994; Ling 1989). They may have very limited experience of ‘overhearing’ (auditorially or visually) the conversations of others (see section 2.15). Their opportunities to observe how people in different roles address and interact with each other are therefore limited. In addition they are excluded from a source of social knowledge about which words and subjects are acceptable in different situations, and which are not openly discussed.

The ability to request clarification is a pragmatic skill that is particularly important in sustaining face-to-face communication that involves speechreading. Jeanes and colleagues (2000) found that oral deaf students (aged eight to seventeen years) requested clarification more often than hearing students, but that these requests tended

to be less specific and therefore less effective. In addition, the deaf students were less likely to respond to a request for clarification by modifying their utterance, and more likely to simply repeat it. The researchers concluded that the deaf students recognized communication breakdowns and sought to repair them more often than the hearing group, but that their repair strategies were less mature. Recognizing and responding to the need for more frequent clarification requests may be a positive adaptive strategy for the deaf students since speechreading during a conversation is difficult and information may often be missed. Interestingly, repetition has also been found to be the type of clarification requested most frequently by adult cochlear implant users during a sentence speechreading task (Tye-Murray et al. 1996). This has been found to be as effective as other repair strategies for these individuals and for normal-hearing adults (Tye-Murray et al. 1990; Tye-Murray et al. 1996). The deaf students may therefore have been providing the type of repair that they find useful when communication breakdowns occurred. The option for repetition (rather than other repair options) should therefore be a consideration in speechreading assessment design, especially where the test is to be used with testees who are expected to find it especially challenging (see section 4.6.i).

2.24 Literacy

“Reading is a basic life skill. It is a cornerstone for a child’s success in school and, indeed, throughout life. Without the ability to read well, opportunities for personal fulfilment and job success inevitably will be lost”

(Anderson et al. 1985, pg. 1)

The relationship between reading and speechreading is particularly interesting because of the enormous educational, social, personal, and economic value of literacy. Both are communication systems that involve the comprehension of visually perceived information, and they are likely to share a number of underlying cognitive functions (e.g. phonological processing, lexical identification; see Rönnberg et al. 1998). However, graphically presented material can be perceived as a synchronous whole, while speechread information cannot since it consists of temporally ordered sets of features (Dodd et al. 1983). The speechreader has little control over the pace at which the message must be received and decoded, and cannot review unless the talker repeats. The reader, on the other hand, sets the pace of reading and can recap as necessary (Silverman & Kricos 1990). In addition, segmentation is provided for the

reader as spaces in the text, and phonological decoding is facilitated by phoneme-to-grapheme correspondence.

The reading ability of severely / profoundly deaf children and adolescents has repeatedly been found to be delayed relative to that of their age-matched peers (e.g. Allen 1986; Conrad 1979; DiFrancesca 1972; Dyer et al. 2003; Kyle 1980a; Lewis 1996; Moog & Geers 1985; Trybus & Karchmer 1977). Several large-scale studies in Britain and the USA have found that deaf people typically show a lag in reading level of approximately 5 years by the time they leave school (Allen 1986; Conrad 1979; DiFrancesca 1972; Trybus & Karchmer 1977). A plateau in the reading development of deaf people has been observed at around the reading age of 9 years (Allen 1986; Wolk & Allen 1984). It should be noted, however, that these comparisons of average achievement levels mask an enormous variation in the reading ability of deaf individuals. Deafness does not always result in poor literacy levels: some deaf individuals become skilled readers (see e.g. Brown & Brewer 1996), and there have been reports of higher levels of reading attainment in select, oral population groups (Daneman et al. 1995; Lewis 1996). For ‘average’ deaf readers, however, difficulties or deficits have been shown at virtually all levels of reading skill, including word recognition and processing (Beech & Harris 1997; Merrills et al. 1994; Waters & Doehring 1990), reading vocabulary (Kyle 1980a), single word reading without context (Harris & Moreno 2004), syntactical knowledge (Arnold et al. 1982; Lillo-Martin et al. 1991; Quigley et al. 1977; Robbins & Hatcher 1981; Wilbur & Quigley 1975), comprehension of grammatical rules (Bishop 1983) and drawing inference from text (Davey et al. 1983; Doran & Anderson 2003).

Deaf people’s difficulty in developing reading skills is likely to be due to a number of factors, mostly related to spoken language knowledge:

- *Vocabulary.* Lexical knowledge is critical to reading comprehension (Bradley-Johnson & Evans 1991; Garrison et al. 1997; Paul 1996; 2001; Quigley & Paul 1989; Smith 1997), but deaf individuals typically have impoverished vocabularies (see section 2.20). It is not therefore surprising that deaf children’s lexical knowledge correlates with, and contributes to, their reading abilities (Anderson & Freebody 1985; LaSasso & Davey 1987; Paul 2001).
- *Word recognition and lexical access inefficiency* (Brown & Brewer 1996). Research suggests that “many deaf readers either retrieve word meanings at great

costs in time and attention, temporarily derailing higher-level comprehension processes, or retrieve inaccurate or imprecise word meanings, also resulting in limited comprehension” (Kelly 1996, pg.77)

- *Reduced syntactic knowledge* (Quigley et al. 1977; Quigley & King 1980; Robbins & Hatcher 1981). Results concerning the relationship between syntactic knowledge and reading in deaf people are inconsistent, and probably depend on the specific participants studied. Some studies have found a significant association (Miller 2000; Moores & Sweet 1990; Quigley & King 1980; Waters & Doehring 1990), while others have found no direct relationship between reading comprehension and syntactical knowledge (Lillo-Martin et al. 1991; Lillo-Martin et al. 1992). Kelly’s (1996) research, however, suggests that syntactic knowledge may be indirectly important for deaf readers. She found that syntactic competence interacts with vocabulary, suggesting that unless a reasonable level of syntactic competence is achieved, it may be difficult for deaf readers to capitalize fully on their vocabulary knowledge (Kelly 1996).
- *Poor phonological coding and processing abilities* (Kelly 1995; Oakhill & Cain 2000; Perfetti & Sandak 2000; Power & Leigh 2000). A number of studies have shown that phonological coding skills and phonological awareness are strong predictors of reading success in deaf children (e.g. Dyer et al. 2003; Harris & Beech 1998; Harris & Moreno 2004). As a group, however, individuals who are deaf show less evidence of phonological coding than their hearing peers (e.g. Burden & Campbell 1994; Harris & Moreno 2004; Merrills et al. 1994; see section 3.7.ii). In addition, whereas for most readers, decoding skills become highly automated after the initial stages of reading acquisition, for some, such cross-modal translations continue to remain difficult (National Reading Panel 2000; Snow et al. 1998). As a consequence, the ability of this latter group (which is likely to include many deaf readers) to use the phonological loop as a buffer for retaining isolated words until they become condensed into meaningful ideas by their final (syntactic) processing is probably reduced (Miller 2002).
- *Limited world knowledge & experience* (Quigley & Paul 1994). ‘Top-down’ deficits, for example in semantics and associated skills such as world knowledge and experience, can limit vocabulary knowledge (see section 2.20) and impact

negatively on deaf children's inferential processes and reading comprehension (Miller 2004).

As in speechreading (see section 3.9), reading involves the interaction of bottom-up (text-driven) processes, and top-down (pre-existing conceptual) processes (see e.g. Quigley & Paul 1994). Johnson (2001) compares the simultaneous management of the multiple tasks associated with skilled reading to juggling – as a juggler manages multiple balls, so attention must be intermittently shifted between processes such as recognising words, analysing syntax, checking comprehension, using prior knowledge, and deducing the writer's goals. Readers with low automaticity, on the other hand, have to focus their attention on basic reading processes, such as word recognition and syntax comprehension, and the other process 'balls' are dropped. This is likely to be the case for many deaf readers, as Kelly (2003, pg. 171) points out, "there is evidence that deaf readers must invest relatively large amounts of mental effort to complete certain basic operations of reading. In other words they exhibit low automaticity, most probably reducing their reading comprehension as a consequence." It has also been suggested, however (again mirroring claims arguments in the speechreading literature, see section 3.9) that deaf children could compensate for problems with bottom-up processes such as phonological recoding and syntax by focussing on top-down information, such as semantic cues, knowledge and experiences (Ewoldt 1981).

Given the number of underlying processes that speechreading and reading have in common, an association may reasonably be expected between them. There has been little research concerning the relationship between speechreading and reading in adults: early work by Simmons (1959), studying hard-of-hearing adults, and O'Neill (1951; O'Neill & Davidson 1956), studying college students, found no significant relationships. However, a number of studies did find significant speechreading-reading correlations for deaf and hard-of-hearing children (Campbell & Wright 1988; Costello 1957; Lowell 1960; Utley 1946). A relationship between speechreading and reading has also been found for hearing school children: good readers may be either good or poor speechreaders, but poor readers are more likely to be poor than good speechreaders (Williams 1982; although see Arnold & Köpsel 1996). However, as Campbell & Wright (1988) noted when considering the significant relationship between their speechreading task and reading in deaf children, the correlations may

reflect the literacy rather than the speechreading component of the speechreading tasks.

More recent research has demonstrated a significant relationship between speechreading and reading skills in deaf children in the absence of confounding literacy factors (Harris & Moreno 2006; Kyle & Harris 2006). Interestingly, Harris and Moreno (2006) found that, amongst the 18 deaf children they tested, all of the good readers were also good at speechreading, however not all of those who were good speechreaders were also good at reading. This suggests that, while speechreading is likely to be extremely important in reading development for deaf children (the authors found that it was a significant predictor of reading even when other factors had been accounted for), being good at speechreading is not sufficient on its own to enable a child to develop good reading skills. Other factors, such as English language skills, are also important. The relationship between reading and speechreading is likely to be complex and reciprocal. Speechreading is related to each of the factors listed above as limiting reading development in deaf people. For example, deaf people develop their phonological code, which is a strong predictor of reading ability (e.g. Dyer et al. 2003; Harris & Beech 1998; Harris & Moreno 2004), largely through speechreading (see section 2.21): Harris and Moreno describe the latter as “the core skill that underpins the capacity for phonological representation” (2006, pg. 197). Speechreading has also been found to predict the development of English language skills such as vocabulary (Dodd et al. 1998). Increased reading ability, in turn, results in improvements in phonological awareness, English vocabulary and syntax, and world knowledge, which may facilitate speechreading.

2.25 Sign language development and its impact on spoken language

The language delays (and/or deviance) displayed by DoH children are a direct result of their inability to access auditory language input, and a lack of sufficient exposure to visually encoded language (Spencer & Meadow-Orlans 1996). Deaf children of deaf parents where the home language is a sign language are known to develop their native language (BSL in Britain) in a parallel way to that of hearing children acquiring their first spoken language. Similar findings have been reported for children developing BSL (Kyle & Woll 1989) and ASL (Newport & Meier 1985; Petitto 1988). As infants, they produce manual babbling (Petitto & Marentette 1991) or ‘mabbling’ (Easterbrooks & Baker 2002) which mirrors vocal babbling. Signs and

words also develop and begin to be combined at similar ages. Hearing and deaf children who have full access to linguistic information continue to communicate in similar ways with their caregivers (Spencer 1993). Although the structure of BSL and English are different in later stages, deaf and hearing children's early signed or spoken utterances are very similar; "thus modality of language has little impact on structure of the earliest word or sign combinations" (Spencer & Lederberg 1997, pg. 223).

There have been reports of DoD children signing much earlier than hearing children typically produce their first words (e.g. Spencer & Lederberg 1997), but this is likely to be due to the misinterpretation of pre-linguistic gestures as signs (Woll 1998). Some studies have reported that children learning to sign have larger early vocabularies than those learning a spoken language (Ackerman et al. 1990). However, any such difference is transitory: children with full access to sign language have a vocabulary size similar to that of those with full access to spoken language (Woll 1998).

Preliminary evidence from children in hearing families where there are alternative models of fluent sign language from an early age (for example, through regular contact with fluent signers in a bilingual early intervention programme) is that their language development does not differ from that of deaf children with deaf parents (Mayberry & Eichen 1991). However, children who have not acquired fluency in a first language (signed or spoken) by the age of five do not subsequently catch up (Loncke et al. 1990; Mayberry & Eichen 1991).

Many of the difficulties that deaf people experience in developing *spoken* language, described in previous sections, also apply to Deaf native signing children. However, their acquisition of BSL (in Britain) also impacts on their spoken language acquisition. They develop lexical representations of the world around them, and syntactical knowledge of their first language as any child with full access to a native language does. Their syntactical knowledge of BSL can intrude into their English as they over-apply learned rules. However their rich language knowledge can also facilitate English language learning. Accordingly, research suggests that native signers' performance in (written) English as their second language parallels that of hearing children who had learnt English as a second language at the same age (Mayberry & Lock 1998). It is therefore unsurprising that Deaf native signing

children have been reported to achieve greater success on a number of measures in comparison with deaf children from hearing families, including mastery of written language (Paul 2001; Strong & Prinz 2000).

2.26 Implications of Sections A to E

Sections A to E have outlined some of the factors that contribute to the heterogeneity of the subgroup of the deaf population that are the focus of the research presented in this thesis: people with a congenital hearing loss of over 90dB. The combination of these factors influences every aspect of a deaf individual's social, emotional and cognitive development, and subsequent lifestyle choices, including their adult language preferences and abilities.

In order to compare congenitally deaf and hearing participants in a more generalisable way than has been done previously, and to investigate the influence of factors which may effect speechreading ability, participants were excluded only on the basis of audiological factors (hearing loss of less than 90dB in the better ear, or reported post-natal onset of deafness), and additional sensory problems or disabilities, and not on the basis of their parental hearing status, education history, or language history or preferences.

The relationships between the effects of the other factors that contribute to the heterogeneity of the deaf population are multifactorial, with different factors interacting in a variety of ways. Each is taken into account as far as possible in later chapters. Of particular interest are:

- **Hearing aid use:** Use of aids is expected to be associated with better speechreading scores because aid users are expected to use spoken English to a greater extent, and the additional (amplified auditory) speech input they experience facilitates everyday speechreading. This is likely to improve the participant's confidence in speechreading, and mean that they are likely to have used speechreading (and therefore practiced the skill) more.
- **Parental language skills and attitudes:** It is not possible to measure the communication skills or preferences of these adult participants' parents, but the communication mode used at home during their childhood will be reported. Those who report having used BSL with their parents may be expected to have better language skills, which may impact positively on their speechreading skills. However, those who report using speech with their parents may be more likely to

continue using speech throughout their lives and may be more motivated to develop better speechreading skills. This latter group is predicted to show better speechreading skills as adults.

- **Parental hearing status:** Both groups of deaf participants have advantages for speechreading: those with deaf parents (DoDs) are expected to have had a richer early language experience, resulting in superior literacy and cognitive abilities. Those with hearing parents (DoHs), on the other hand, are expected to have had access to a better model of spoken English at home, and a stronger early motivation to learn the speechreading skills needed to understand it. Neither group is therefore predicted to outperform the other.
- **Type of schooling:** Participants educated in mainstream or other oral settings are expected to have better English language skills, and therefore better speechreading skills. A mainstream or oral placement may have provided opportunities for bootstrapping English language abilities, however it should be remembered that relative proficiency in English is likely to be as much a cause as a result of such a placement. A subgroup of the orally educated participants will have been to an oral school that has academic entrance requirements, and the older participants are only likely to have received a manual-based education if the oral method had been tried and deemed to have failed.
- **Language choice:** Participants who choose to use spoken English to a greater extent in their everyday lives are expected to have better speechreading skills. They are likely to have chosen to use speech because they have good English language skills, and through use, continually practice their speechreading skills.

The speechreading abilities of the deaf adult participants will be investigated as a function of each of these factors in Chapter 6 to identify which define subgroups of participants with superior speechreading performance, and which make independent contributions to the variance in speechreading performance.

Section F: Hearing people with d/Deaf Parents (HoD)

Hearing people with deaf parents will be labelled HoD (Hearing of Deaf) throughout this thesis to be consistent with the other group labels. They have been labelled with a number of terms and acronyms in the literature (Preston 1994), including Hearing Children of Deaf Parents (HCDP), Deaf Parented Family (DPF), Interpreters of Deaf

Parentage (IODP), Adult Hearing Children of Deaf Parents (AHCDP), and, most commonly in the USA, Children Of Deaf Adults (CODA¹⁰).

Approximately 90% of deaf adults have hearing children (Schein & Delk 1974; Singleton & Tittle 2000). Hearing children born to Deaf parents are usually considered bilingual and bicultural. They potentially share the language and culture of their parents (depending on the communication, cultural, and educational choices of their parents), and because they are hearing, will inevitably become members of the hearing community and acquire the language spoken by their majority community. The majority of HoD children develop spoken language normally, without showing a language delay, through exposure to normal-hearing speakers (Hoffmeister 1985; Preston 1994; Schiff-Myers 1993; see section 2.27). Many HoDs provide assistance and advocacy, and interpret for their parents from childhood into their adult lives (Preston 1994). Their unique position between the Deaf and hearing worlds gives them a rich understanding of all aspects of visual language (spoken and signed). Because of their insights into the implications of deafness and their skills in sign language, some HoD people choose to work with deaf people in adulthood.

Deaf mothers of hearing children report that, “although they know their child can hear, they find it difficult to communicate if their child is not looking at them” (Woll & Kyle 1989, pg. 141). Accordingly, deaf mothers expend more effort in gaining their children’s attention (Woll & Kyle 1989). As a result of this and the richness of the visual communication environment provided by deaf, signing mothers (Spencer 2000) their hearing children (like DoD children) spend more time looking at them than hearing children with hearing mothers.

HoD participants may be expected to show superior speechreading skills in comparison with their HoH peers as a result of their increased awareness of the visual properties of language.

¹⁰ This acronym is particularly common, and was chosen as the name of an organisation for hearing people who grew up with at least one deaf parent in the USA by its founder because of the musical term’s metaphorical parallel with its members: a concluding musical section that differs from the main structure (Preston 1994).

2.27 Spoken Language Development in Hearing children of Deaf Parents

Adult hearing individuals with deaf parents (HoD) are often bilingual and bicultural. Most anecdotal reports from HoD children indicate that they believe they learned sign language as their first language and learned oral language from hearing adults (e.g. Fant & Schuchman 1974; Vernon 1974). However, this may not necessarily be the case. Mothers who are deaf have been reported to underestimate the predominance of their oral input to their hearing children (Mayberry 1976; Schiff-Myers 1982). Woll and Kyle (1989) found that they “initially used spoken language in their earliest interactions with the child to the exclusion of British Sign Language” (pg. 137), and later (in the child’s second year) articulated English words while signing. Some deaf mothers with limited spoken language have nonetheless been found to order their oral language according to English syntax, even when their MLUs were under 2.0 and they were less than 2% intelligible (Schiff-Myers 1982).

Many aspects of communication have been reported to be unaffected by the linguistic input of parents who are deaf (Schiff-Myers 1993). For example, the use of language for interactional purposes, discourse development, and the semantic relations of language (i.e. the content) have not been reported to be adversely affected. In addition, HoD children have not been found to develop a ‘deaf’ voice quality (see e.g. Schiff & Ventry 1976), although they sometimes communicate using voiceless speech. Atypical stress patterns have been found in some HoD children’s speech (Schiff-Myers & Klein 1985), but the incidence has not been shown to be different from that found in children with hearing parents, and the errors may reflect no more than normal variation (Schiff-Myers 1993). Problems in fluency (stuttering and cluttering) have also been observed (Schiff & Ventry 1976), but may not be directly attributable to the parents’ deafness.

2.27.i Phonological development: While some normal-hearing children of deaf parents have articulation problems, many do not (Brelje 1971; Leonard et al. 1980; Mayberry 1976; Schiff 1979; Schiff & Ventry 1976; Schiff-Myers 1993). Leonard and colleagues (1980) studied the phonology of a HoD child as he developed his first 50 words. Only some of his earliest productions could be attributed to the influence of his deaf mother. Schiff-Myers and Klein (1985) compared the phonological processes used by five HoD children with those used by HoH children and those used by their mothers. They found that none of the HoD children adopted their mothers’

idiosyncratic articulation patterns, either in their spontaneous speech or when they imitated their mothers. Their modifications were more like those of other children described in the hearing developmental literature (e.g. Klein 1981; Preisser 1983).

2.27.ii Syntactical development: When problems do occur in the syntactical development of HoD children, it is assumed that they are related to mapping oral language onto a sign language syntactic base (Murphy & Slorach 1983; Todd & Aitchison 1980; Todd 1975). This is similar to reports of other children who are simultaneously acquiring two languages (McLaughlin 1981).

In summary, although the early spoken language of hearing children with deaf parents may be influenced by their unique linguistic environment, the process of language development is 'well-buffered' (Snow 1994), and successful development is rarely a problem for these children. Their increased visual attention to their communication partner's face may, however, cultivate their speechreading abilities.

2.28 Summary

In this chapter, the factors that contribute to the heterogeneity of the deaf population, and which contribute to the differences between the life experiences of deaf and hearing adults have been outlined. A number of factors have been identified for investigation in later chapters as they may affect the speechreading abilities and strategies of the deaf participants in this thesis. These include cause and age at diagnosis of deafness, hearing aid use, tinnitus, communication mode experience and preference, type of school, and parental hearing status. In addition, Section E has shown that the spoken language of deaf individuals differs from that of hearing individuals throughout development, from the earliest stages in infancy. The effects of these differences are pervasive and likely to have an enormous impact on the spoken language processes and representations of deaf adults. The focus now shifts to this adult speech processing in Chapter 3.

Chapter 3

ADULT SPEECH PROCESSING AND SPEECHREADING

3.1 Introduction

It has been seen in Chapter 2 that congenital deafness has a profound impact on every aspect of spoken language development. The social, educational and linguistic experiences of people who are deaf differ enormously from those of hearing people, and it is therefore unlikely that the processes involved in speechreading are identical for deaf and hearing individuals. In this chapter, speech processing in profoundly congenitally deaf and hearing adults will be considered.

Speechreading, as it is defined here, entails processing a speech signal that is perceived through vision alone. Models of perceptual speech processing have historically been auditory. More recently, the need to account for the role of vision in auditory-visual speech processing has been recognised. There has, however, been no specific model of speechreading alone. The majority of the research on speech processing has, accordingly, focussed on auditory or auditory-visual processing, and this body of knowledge informs our understanding of the processes underlying speechreading. This chapter provides an overview of the processes involved in decoding and understanding spoken English, focussing on speech processing when only visual information is available.

Extracting meaning from speech is a complex and still incompletely understood process. Models of bottom-up spoken word recognition assume that speech processing involves matching the perceived speech signal to stored representations of words in the lexicon (see e.g. Luce & Pisoni 1998; Marslen-Wilson 1987; McClelland & Elman 1986). This applies to speechreading as well as to audiovisual spoken word recognition (Lyxell et al. 1994; Puce et al. 1998). Activation of and competition between stored lexical forms results in word recognition when one of the lexical forms is selected, or discriminated, from the others (Forster 1979; Marslen-Wilson 1987; 1989; 1993; McClelland & Rumelhart 1981; Morton 1979; Norris 1994). How is this matching of perceived and stored lexical items achieved when perception is through vision alone? In the sections that follow, this question will be addressed by

focussing on eight aspects of visual speech and language processing:

- How is the speech stream segmented into units that can be matched to stored representations?
- What is visible in the speech stream at the segmental level?
- What aspects of visually perceived speech signals are important?
- What are the ‘objects of perception’ for audiovisual (and visual) speech?
- How do perceivers cope with the variability in speech production?
- How is speechread information processed and stored in working memory?
- Is phonological coding the same in deaf and hearing people?
- What is the role of top-down processing?

3.2 How is the speech stream segmented into units that can be matched to stored representations?

In order to make sense of segmental and suprasegmental information in the speech stream, it needs to be segmented into lexical units. However, fluent speech is continuous and the sounds co-articulated such that the word boundaries are concealed (Cole & Jakimik 1980; Lehist 1972). Understanding this continuous stream requires it to be mapped to discrete lexical entities. The cues used to identify word boundaries differ across languages (Johnson et al. 2003; Sanders & Neville 2003b). Since this thesis is concerned with speechreading English, the English word boundary cues will be focussed on here.

Word recognition is assumed to involve activation of, and competition between, lexical candidates in long-term memory. These processes enable the appropriate segmentation of the speech input to be identified in models of adult word recognition (e.g. Luce & Pisoni 1998; Marslen-Wilson 1989; McClelland & Elman 1986; Norris 1994). The exact cues in the speech stream that are used to activate lexical items is still debated (see section 3.5), but assuming that all the words in an input are in the perceiver’s lexicon, competition between potential lexical candidates alone may be enough to segment the speech stream successfully (Johnson et al. 2003). However, all speech perceivers encounter input for which they have no lexical representation at times. Profoundly congenitally deaf individuals may do so frequently since their English vocabularies are often impoverished, and the degraded nature of the speech signal that they perceive renders many words unintelligible. Further, young children who are learning their native language need to segment the speech stream in order to

access and learn lexical items. Lexical competition cannot be used in segmentation until the lexical items have been learned, so alternative methods of segmentation must be available and used.

3.2.i The possible-word constraint (PWC)

Norris and colleagues (1997) considered the problem of how adults successfully deal with unknown lexical items and discount implausible segmentations when utterances contain such items. They found that adults detected words embedded in nonsense words more easily when the residual context was a syllable than when it was a single consonant. For example, 'apple' was detected in "vuffapple" more easily than in "fapple". To account for this, they proposed that segmentation is facilitated by a bias against any segmentation that leaves a single consonant as a residue: each perceived segment in the speech stream should be accounted for by a possible word (the 'possible-word constraint', Norris et al. 1997). These results were not due to acoustic syllable boundary cues: cross-spliced materials produced the same pattern of results; and in subsequent experiments, it has been demonstrated that it does not matter whether the segments are possible words in the perceiver's lexicon (Cutler et al. 2002; Norris et al. 2001). In other words, syllables seem to have a special status in speech segmentation because, potentially, they can be lexical items (whereas single consonants cannot). This constraint seems to operate without reference to the lexicon: it is simply a bias against any segmentation that results in items that could not hypothetically be possible words. It may therefore be particularly useful to those with limited vocabularies, provided they have enough lexical knowledge to be sensitive to potential syllables. In addition, the articulatory movements associated with syllable production can be usually be perceived visually as well as auditorially. This constraint is therefore broadly available to the speechreader. However, Norris and colleague's work is with auditory speech in hearing people, and as such, there is an assumption in that all of the speech stream is perceived. Whilst all of the speech stream can be heard (at least in their experimental conditions), many segments may be missed or perceived erroneously when speech is perceived by sight alone. Velar consonants, for example, are difficult to perceive visually. An initial or final syllable that respectively starts or finishes with a velar consonant may therefore be missed as an assumed preparatory gesture. Conversely, silent lip closures may be perceived as bilabial consonants, or the articulatory movement of a talker preparing to speak may be

perceived as an initial syllable. Since the speechreader cannot be sure s/he has perceived all of the segments of the speech stream, s/he may need to make comparatively more use of additional cues (e.g. syntactic information, semantic information, stress patterns, and/or phonotactic information, see below) to segment the speech stream successfully.

3.2.ii Words, semantics, and syntax

Although the syllable is an important unit in audiovisual speech segmentation, it is the word onsets (rather than the syllable onsets) that are recognised in initial parsing. They are recognised even when semantic and syntactic information has been minimised (Sanders & Neville 2003a). Word onsets are particularly important in segmentation: they have been identified as the “loci of acoustic-phonetic factors affecting segmentation” (Gow et al. 1996; pg. 66). It has been noted that most hypothesized prelexical juncture cues, including phoneme lengthening, glottalization or laryngealization of vowels, aspiration of voiceless stops and the occurrence of strong syllables, occur at the beginnings of words (Gow & Gordon 1995). Processes of assimilation, normalization and deletion occur across word boundaries in connected speech, impeding segmentation. For example, the final stop consonant of one word may assimilate to, or delete, the following word initial consonant (e.g. fat cat -> “/fak/ cat”). However, word initial consonants do not assimilate to a preceding word-final consonant. Word onsets, then, are the richest and least variant parts of words, hence their description by Gow and colleagues (1996) as “perceptual islands of reliability in normal reduced connected speech” (pg. 66).

Semantic and syntactic information may normally be utilised in speech segmentation if available (see e.g. Sanders & Neville 2000). Perceivers may make use of whatever cues are available to segment the speech stream, making greater use of the less individually informative cues when others are absent, as is undoubtedly the case in visual-only speech perception. Alternatively, semantic and syntactic information could be used in top-down re-segmentation of speech rather than in initial parsing (Sanders & Neville 2003a).

3.2.iii Prosodic cues

In English, strong syllables (which bear stress and are never shortened to neutral vowels) are likely to be the initial syllables of content-bearing words. In contrast, weak syllables (which do not bear stress and are often shortened to neutral vowel

sounds) are either not word-initial, or start a function word (Cutler & Carter 1987). In addition, the duration of the hold phase of consonants is increased for stressed syllables, and particularly for word initial consonants (Umeda 1977). This decreases the amount by which a consonant is ‘co-produced’ with adjacent segments: it reduced coarticulation effects. Cutler and Norris (1988) proposed that English listeners might use knowledge of these stress patterns to make an initial assessment of the location of the potential onsets of words in fluent speech; they termed this the ‘metrical segmentation strategy’. Subsequent empirical research has shown that, in a stress-based language such as English, listeners do insert word boundaries before stressed syllables (Cutler & Butterfield 1992; McQueen et al. 1994; Vroomen & de Gelder 1995). This stress-based segmentation results from native exposure to a stress-based language – it does not occur in languages such as French, which have clear, unambiguous syllables: in these languages an alternative syllable-based segmentation is used.

English may not be the first language of many British deaf individuals, (see Chapter 2, Section B), but it is likely to be their first *spoken* language, and they will have been exposed to it from birth to some extent (visually, whenever they looked at a speaking person). It is not clear, however, to what extent prosodic information such as lexical stress and sentence focus can be perceived reliably through speechreading alone: an initial investigation of this question is undertaken in Chapter 7. Since the acoustic spectral correlates of stress include changes in amplitude of voiced speech frequencies, residual hearing and any vibrotactile cues available from powerful hearing aids may facilitate the perception of prosodic information by deaf individuals in everyday speech perception.

3.2.iv Phonotactic and allophonic cues

Knowledge of native language phonotactic patterns has been suggested as another source of information about potential word boundaries in fluent speech (Brent & Cartwright 1996; Cairns et al. 1997; McQueen 1998; van der Lugt 2001; Vitevitch & Luce 1998; Vitevitch & Luce 1999). For example, certain phonotactic patterns occur much more frequently between words than within them. Adult perceivers take advantage of these patterns, using them in segmentation to signal the likely location of word boundaries, and so recognize words (McQueen 1998; Vitevitch & Luce 1999).

Another source of information in the acoustic signal that potentially cues word boundaries is allophonic¹¹ (Bolinger & Gerstman 1957; Church 1987; Hockett 1955; Lehiste 1960): allophones of a given phoneme are often restricted with respect to their position within words. The aspirated allophone [t^h] of the English phoneme /t/, for example, occurs at the beginning of stressed syllables, whereas the unaspirated allophone [t] occurs word-finally. Church (1987) suggested that listeners might use information about the presence of such context-specific allophones in segmenting words from fluent speech. Speechreaders can, identify phonemic information in spoken sentences (see e.g. Bernstein et al. 2000), and so could potentially make use of phonotactic information. However, the majority of allophonic information, such as aspiration, is virtually impossible to perceive through speechreading alone. Where allophonic variation is visible, for example rounded or spread lips on /f/ depending on the following vowel, it is unlikely to be informative in terms of speech segmentation because the restriction is not word position based.

Hearing individuals have a much richer experience of phonological and phonotactic information than their deaf peers. When they attempt to speechread they are therefore in a position to make more use of any phonotactic information that they are able to perceive, although this is likely to be extremely limited. Some deaf individuals, on the other hand, are able to visually perceive a higher proportion of the phonemes in sentences than their hearing peers (Bernstein et al. 2000) and are more sensitive to the distinctions between words which are visually highly confusable, such as ‘bat’, ‘pat’, and ‘mat’ (Bernstein et al. 1997; see section 3.3). These skilled speechreaders may develop an awareness of *visually* based phonotactic information that they can make use of in segmenting the speech stream.

The various cues to the location of word boundaries (with the exception of the possible-word constraint) are probabilistic and therefore need to be integrated. Given that there should be no residual segment that does not include at least one vowel, any conflicts in the possible word boundaries need to be resolved. Some evidence suggests that, soon after children learning English begin to segment words, they tend to rely more heavily on the prosodic stress cues when there is conflict (Johnson & Jusczyk 2001; Mattys et al. 1999). Prosodic stress may also be an especially

¹¹ Allophones are the phonetic variants of a phoneme, for example [f[~]] and [f] are allophones of the voiceless palato-alveolar fricative /f/ in English.

important cue for speechreaders, since the stressed portions of the signal tend to be easier to perceive. The effect of coarticulation on consonants is reduced, and the vowel is not reduced in stressed syllables: stressed vowels are amongst the easiest phonemes to identify visually (see section 3.3.ii).

3.3 What is visible in the speech stream at the segmental level?

One of the problems facing the speechreader is that there is less phonemic information available by eye than there is by ear. This is because, while information about the linguistically relevant state of all of the vocal organs is available in the acoustic signal (Stevens 1998), not all vocal tract actions are visible. Many phonemes, therefore, look almost identical on the lips (Berger 1972d; Jeffers & Barley 1971). For example, information about the state of the velum, which determines nasality, or about the state of the larynx, which determines voicing, does not readily reach the eye. Woodward and Barber (1960) state that, “of those phonetic dimensions which define the significant articulatory differences in English speech, almost all – including articulation type, resonance type, voice, affrication, palatalization, and all areas of articulation except the labial – are virtually neutralized as factors of difference in visual perception” (pg. 219). It is not surprising, then, that visual phoneme identification rates in nonsense syllables are low, particularly for consonants, which are typically identified with an accuracy level of between 19% and 46% (Auer & Bernstein 1997; Owens & Blazek 1985).

Given the reduced phonetic information that is available to the speechreader, it has been considered useful to identify the phonemes, or groups of phonemes, that *can* be perceived through vision alone. The term ‘viseme’ has become accepted to describe a perceptual category of visually perceived phonemes (e.g. Massaro 1998). Visemes are “speech elements that look identical when lipreading, e.g., /p, b, m/” (Kricos & Lesner 1985, pg. 5). The term was coined by Fisher (1968) as a shorthand for ‘visual phoneme’, and defined then as the visible analogue to the phoneme because it is the smallest unit of visually perceived speech, just as the phoneme is often considered the smallest unit of auditorially or audio-visually perceived speech. However, phonemes are not acoustic entities, but linguistic abstractions defined by their contrastive power within a language (Gleason 1961). A phoneme is a set of phones (speech sounds or sign elements) that are cognitively equivalent and that the speakers of a language think of, and hear and/or see, as being categorically the same. It is the basic unit that

distinguishes between different words or morphemes: changing an element of a word from one phoneme to another produces either a different word or obvious nonsense, whereas changing an element from one phone to another, when both belong to the same phoneme (i.e. are allophones), does not change the word meaning. Phonemes are not the physical segments themselves, but mental abstractions of them. Visemes, on the other hand, are defined by their visual properties. They are groups of one or more phonemes that alter as a function of the talker, speechreader, material being spoken and conditions under which it is perceived.

3.3.i Consonants: There has been disagreement about the proportion of visually perceivable consonantal phonemes. For example, Woodward and Barber (1960) conducted a discrimination experiment with pairs of CV (consonant-vowel) nonsense syllables selected on the basis of feature analysis and a theoretical scale of perceptual dissimilarity (they did not test every phonemic contrast in English). Their aim was to discover the minimal perceptual units of speechreading. They concluded that only four sets of English consonant initials that could be classified as visually contrastive:

- 1.) 'Bilabial': /p, b, m/
- 2.) 'Rounded labial': /hw, w, r/
- 3.) 'Labio-dental': /f, v/
- 4.) 'Non-labial': /t, d, n, l, θ, ð, s, z, tʃ, dʒ, ʃ, ʒ, j, k, g, h/

They further concluded that the derived groupings were perceptual units, and if speechreaders are able to distinguish between the within-group phonemes (e.g. between alveolar, dental, alveopalatal, velar, and glottal consonants), "it must be on the basis of phonetic, lexical, or grammatical redundancy, since the articulatory differences among them are not readily available to visual observation" (Woodward & Barber 1960, pg. 219). Kaczmarek (1990), on the other hand, presents a visual classification of English phonemes stating that it is possible to visually distinguish features characteristic of individual sounds.

Walden and colleagues (1977) identified nine visemic categories from nonsense syllable confusions matrices obtained during identification tasks:

- | | | |
|---------------|------------------------|--------------------|
| 1.) /b, p, m/ | 4.) /ð, θ/ | 7.) /ʃ, tʃ, ʒ, dʒ/ |
| 2.) /w/ | 5.) /d, t, n, g, k, j/ | 8.) /r/ |
| 3.) /v, f/ | 6.) /s, z/ | 9.) /l/ |

The phonemes were assigned to viseme groups using cluster analysis: at least 75% of the responses to each phoneme were phonemes within the same cluster. This method has become standard for reducing confusion data to visemes (e.g. Owens & Blazek 1985). However, the need to use cluster analysis itself indicates that visual speech perception is not as categorical as the concept of the viseme implies (Bernstein 2004). If visemes were discrete perceptual categories, responses would all be within the viseme clusters, and cluster analysis would not be needed. In fact, visemic categories, though fairly systematic, are far from invariant (cf. Owens & Blazek 1985). Optimal performance (the maximum number of visemic categories that an individual can perceive) is achieved only when the perceiver is familiar with the task and the talker, lighting illuminates the tip of the tongue, and the consonants are articulated carefully but naturally in the context of open vowels (e.g. /aCa/) so that the positions of the tongue and teeth can be seen (Benguerel & Pichora-Fuller 1982).

3.3.ii Vowels: Monophthongal vowels can be identified visually nearly perfectly by good speechreaders under optimal conditions; that is, when they are produced carefully by a single talker in a consonantal context that demarcates the duration of the syllable and does not impede the vowel lip shape (e.g. /dVd/, rather than /fVf/) (Montgomery et al. 1987). The visual differences between vowels are graded and continuous (Heider & Heider 1940). Their visual distinctiveness is largely because a major distinguishing feature of vowels is the height of the tongue in the mouth, which is highly correlated with the vertical separation of the lips. Stressed vowels are therefore reasonably well specified by the degree of vertical and horizontal lip separation and duration (Fromkin 1964; Montgomery & Jackson 1983). Differences in the visibility of the teeth also play a limited but systematic role (McGrath, 1985, cited by Summerfield 1991).

3.3.iii The impact of visemes in speechreading

The optimal conditions required for identifying consonants and vowels visually, such as minimal coarticulation and careful well-lit production, are rarely, if ever, found in spontaneous everyday speech. There has been disagreement about effect of visemes (that is of the limited phonemic information available visually) on speechreading words and sentences. Early estimates claimed that around fifty percent of the English words used in typical conversation are homophonous, that is they sound different, but

look the same to the speechreader (Berger 1972d; Nitchie 1916; Vernon & Mindel 1971). This has been shown to represent the typical performance of hearing adults on speechreading tasks (Auer & Bernstein 1997).

Auer & Bernstein (1997) used the term ‘Phonemic Equivalence Class’ (PEC), to describe sets of perceptually similar phonemes – Bernstein (2004) describes the PEC as “the generalization of the viseme” (pg. 24). For example, the set /b, p, m/ is a typical PEC. Using lexical modelling, with PECs derived from experimental data on the visual confusability of the phonemes of American English, they showed that 12 PECs resulted in an estimated 54–63% of the words of the lexicon remaining distinct. This is in line with the typical speechreading performance of hearing adults, and the 12 PECs are consistent with earlier estimates of the phonemic distinctions possible in visually-perceived speech (Jackson 1988).

The 12 Phoneme Equivalence Classes identified by Auer & Bernstein (1997):

- | | | |
|--------------------|------------------------|--------------------|
| 1) [u, ʊ, ə] | 5) [ɔ, aɪ, ə, a, ʌ, j] | 9) [d, t, s, z] |
| 2) [o, aʊ] | 6) [b, p, m] | 10) [w, r] |
| 3) [ɪ, i, e, ε, a] | 7) [f, v] | 11) [ð, θ] |
| 4) [ɔɪ] | 8) [l, n, k, ŋ, g, h] | 12) [ʃ, tʃ, ʒ, dʒ] |

The high degree of visual distinctiveness demonstrated within the English lexicon for just 12 PECs derives from the segment inventory and phonotactics of English (MacEachern 2000). English has fairly free phonotactics and a large segment inventory, resulting in a large lexical space (Maddieson 1984). In other words, there are many *potential* English words; however, a fairly low percentage of these are *actual* words (Hockett 1958). One consequence of this is that relatively few words in English have close neighbours in (phonologically defined) lexical space. In principle, therefore, a relatively large proportion of English words may be identified on the basis of their visemic (or PEC) properties. The extent to which *real* speechreading reflects these statistical properties is another matter again, since not every viseme will be correctly identified by every speechreader.

Typical or mean speechreading performance figures of around 50% are expected given the visemic quality of many of the phonemes of English, and the visual distinctiveness of the English lexicon. However, such figures mask the large variability in speechreading performance: skilled speechreaders are able to achieve accuracy levels that far exceed expectation. In other words, some speechreaders are

able to distinguish between words that are considered homophenous – they can perceive ‘sub-PEC’, or ‘sub-visemic’, information (Bernstein et al. 2000; Bernstein 2004). This ability is likely to be related to (as a result and/or a cause of) other aspects of speechreading skill, such as segmentation (see section 3.2), and phonological coding, processing and representation (see sections 3.7 and 3.8).

That highly skilled speechreading is possible could be thought of as a demonstration that speech perception is resistant to a reduction in phonetic information. Phonemes can be described in terms of a number of phonetic characteristics, and these typically vary across phonetic contexts (Liberman 1982; Lisker 1978). While acoustic phonetic cues are each “by definition more or less sufficient, none is truly necessary. The absence of any single cue, no matter how seemingly characteristic of the phonetic category, can be compensated for by others, not without some cost to naturalness or even intelligibility, perhaps, but still to such an extent that the intended category is, in fact, perceived” (Liberman & Mattingly 1985, pg. 11-12). The extreme of speech perception resistance is demonstrated by the perception of sinewave speech. Sinewave signals are three-tone sinusoidal replicas of naturally produced speech. They are synthesized to track the pitch and amplitude of the centre formant frequencies of an utterance, but lack transitions and noise bursts. With training, listeners are able to identify the linguistic message in such stimuli despite the absence of classical phonetic attributes (Remez et al. 1981). Sinewave speech perception demonstrates that, given normal experience with acoustically well-defined speech, speech that has been systematically filtered to minimal spectrotemporal input can be perceived.

3.4 What aspects of visually perceived speech signals are important?

The demonstration with sinewave speech and auditory speech perception prompts the question, what aspects of the *visually* perceived speech signal are important in decoding an utterance? Sinewave stimuli preserve the time-varying properties of auditory speech in the absence of traditional acoustic phonetic cues, i.e. spectral formant frequencies (Remez et al. 1981). Remez and colleagues demonstrated that this information alone can be sufficient to convey the meaning of an utterance. One possibility, then, is that the time-varying aspects of *visually* perceived speech are similarly important

3.4.i Time-varying (dynamic) and time-independent (static) information for speechreading

Time-independent information: Most descriptions of visual speech information have focussed on static facial positions, such as lip shape and the visibility of the teeth and tongue (Braidá 1991; Massaro & Cohen 1990; McGrath 1985; Montgomery & Jackson 1983; Summerfield & McGrath 1984). For example, Montgomery and Jackson (1983) described the visual information for vowels in terms of tongue height and the degree of lip spreading or lip rounding. These features could be captured in a photograph, and the implication is that the aim of visually decoding vowels (and consonants) is to look for, and match to, an idealised articulatory position. Rosenblum and Saldaña (1998) suggest that the reason that most descriptions of visually perceived speech are form-based is that they “have been (tacitly) based on descriptions of general visual and face perception information” (pg. 63). The majority of research on general visual perception has concerned objects (see Marr 1982), and we perceive faces (the conveyers of visual speech information) by recognizing static features such as the shape and configuration of the eyes, nose and mouth (see Bruce 1988). Certainly, static photographs can convey visual speech information: people are able to identify a specific consonant or vowel from a photograph of a person articulating it (Campbell 1986; Campbell et al. 1986). Time-independent information may also influence auditory perception in McGurk effect tasks (Campbell 1996; Cathiard et al. 1992; Cathiard & Tiberghien 1994; but see Rosenblum and Saldana, 1996). However, this does not necessarily imply that time-independent features are the most salient or useful in speechreading. The static cues in speech could be thought of as analogous to the information provided by a photograph of an event such as a swinging tennis racket – they are informative to a degree, but are only “impoverished approximations of the time-varying information and are not what perceptual systems have evolved to recover” (Rosenblum & Saldana 1998, pg. 65).

Time-varying information:

“Speech is rather a set of movements made visible than a set of sounds produced by movements” (Stetson 1928)

There are correspondences between the movements of the talker’s face and head during speech, and the acoustic signal produced. For example, Munhall and colleagues (2004) reported that head movements are quite well temporally aligned

with the onset and offset of voicing in sentences. The time-varying, visual kinematic properties of spoken phrases have been found to correlate systematically with the spectral (acoustic) properties to the extent that the visible motion of the mouth, face and head can be used to predict and ‘recapture’ almost all of the speech acoustic patterns, and vice versa (Vatikiotis-Bateson & Yehia 1996; Yehia et al. 1998; Yehia et al. 2002). This suggests that visual spatio-temporal speech patterns afford reliable access to representations of phrase-length utterances.

The salience of time-varying information for visual speech processing has been investigated most directly using point-light displays (Brooke & Summerfield 1983; Rosenblum et al. 1996; Rosenblum & Saldana 1996; Summerfield 1979). There are various ways to produce point-light speech displays. In one technique, small florescent dots are positioned around a talker’s lips, and sometimes additionally on the cheeks, chin, teeth and tongue tip (Rosenblum et al. 1996), while the rest of the talker’s face, including the inside of the mouth, is blackened. Video recording under florescent black lights produces images in which only the dots and their movements can be seen. These stimuli cannot be recognized when they are static, but are easily identifiable when moving. That is, they isolate time-varying, dynamic visual information from time-independent, pictorial or form information¹². The dynamic information available from point light displays is salient for speech perception. It has been found to enhance the perception of speech presented in noise (Rosenblum et al. 1996), and has a small, but measurable, influence on auditory perception in McGurk effect tasks (Rosenblum & Saldana 1996; this effect, first described by McGurk & MacDonald 1976, is described in section 1.3). A further demonstration of the salience of the time-varying characteristics of the visual signal has been provided by spatial frequency filtering of the image. This manipulation also differentially affects the visibility of specific face features. As long as the temporal characteristics of the signal are maintained, low-pass spatial frequency filtering blurs the image without markedly compromising audiovisual gain for understanding spoken sentences (Munhall et al. 2004).

¹² When point light techniques (first described by Johansson 1973) are used to generate biological motions of other types, they convey rich information about the action pattern and the actor. For example, perceivers can identify the gender of a walking actor (Kozlowski & Cutting 1977), the relative weight of an object being lifted (e.g. Bingham 1987), and, when applied to human faces, facial identity, emotional expressiveness, and age-related ‘person qualities’ (Bassili 1978; Berry 1990; Bruce & Valentine 1988).

Neuropsychological dissociations also suggest that the dynamic, time-varying characteristics of seen speech are important in audiovisual and visual speech processing. One patient, H.J.A. (described by Humphreys & Riddoch 1987) with a profound deficit in identifying visual forms (visual agnosia) due to damage to occipito-temporal brain regions (damage to the ventral visual stream) was susceptible to the McGurk illusion, although he was unable to identify any speech gestures from photographs of the mouth and face alone (Campbell & Perrett 1992). By contrast, a patient with an acquired cortical blindness for visual movement was unable to speechread natural speech, despite good identification of speech-patterns from photographs (Campbell et al. 1997).

Speech, whether heard or seen, appears to rely critically on information carried in its dynamic properties – properties associated with its articulation (Summerfield 1987). However, time-independent information may also have a role in speech perception: point light speech stimuli are not as informative as fully illuminated talking face stimuli. This may be because point lights, as points, cannot provide *all* of the useful dynamic information available in a fully illuminated talking face, or because observers are simply less experienced with point-light faces (Rosenblum & Saldana 1998). It seems likely, however, that it is because time-independent information also contributes salient information for visual speech perception. The relative importance of dynamic and static visual speech information for speechreading will be considered further in Chapter 8.

3.4.ii Oral and extra-oral speech signals

Point light configurations are informative for visual speech perception when the points are located on the lips alone providing there are sufficient, informatively placed points (Rosenblum et al. 1996). The four points used by Summerfield (1979) did not convey enough information to provide any more than a marginal improvement in comprehension. Adding additional points to the teeth and tongue tip improved comprehension performance, although extra-oral points did not (Rosenblum et al. 1996). In investigations of fully illuminated face movements, however, both perioral (lip) and extra-oral (e.g. cheek) movements of the face have been found to contain substantial information about the acoustic structure of speech: “the system controlling lip and jaw motion dynamically affects the entire facial structure below the eyes” (Munhall & Vatikiotis-Bateson 1998, pg. 132). Further, the combination of lip and

peripheral information has been found to be more informative than either in isolation (Munhall & Vatikiotis-Bateson 1998), and to better predict acoustic spectral properties of the speech signal (Yehia et al. 2002). This suggests that the movements of the lips and of other face regions provide potentially independent information for the perceiver. It is not therefore surprising that speechreading performance is better when other areas of the face are visible in addition to the lips than when only the lips can be seen (e.g. Guiard-Marigny et al. 1995; Larr 1959).

3.5 What are the ‘objects of perception’ for audiovisual (and visual) speech?

Potential objects (or primitives) of speech perception that have been proposed include the auditory qualities of the phonetic segments (Diehl & Kluender 1989), and the speech gesture itself (Lieberman & Mattingly 1985), characterized by its motoric, acoustic, visible and somasthetic correlates. In auditory theories, such as the auditory enhancement hypothesis (Diehl & Kluender 1989), it is proposed that listeners are primarily sensitive to the auditory qualities of phonetic segments and it is those qualities that define the multidimensional phonetic space. Visual characteristics are mapped into this space by their association with specific phonetic representations. Such theories do not account for speech perception by deaf people through speechreading. Congenitally profoundly deaf individuals have extremely distorted or non-existent experiences of the auditory qualities of phonetic segments, and yet they are able to recover meaning from speech perceived through speechreading.

‘Gestural’ theories, such as the revised motor theory of speech perception (Lieberman & Mattingly 1985), and the direct-realist perspective on speech perception (Fowler 1986) may more readily account for the speech perception abilities of deaf speechreaders. They suggest that perceivers are primarily interested, not in the patterns of sound that talkers create, but in the articulatory gestures that generate those sounds. Simply the fact that perceivers can recover meaning from speech without sound (i.e. that speechreading is possible), has been taken as evidence in support of the role of gestures rather than sounds (Summerfield 1991). Gestural theories are also better able to cope with the primacy of time-varying information in speech perception (see section 3.4.i: if the objects of perception are dynamic gestures it should follow that the dynamic aspects of the signal are particularly salient and informative, Fowler 1987), and with variability in speech production. Phonemes, as mentioned in section 3.3, are a set of abstractions (Gleason 1961) that do not match their spoken

realisations. Speech segments cannot therefore be identified from spectral cues, especially across different talkers. The speech of different individuals varies widely according to their physical characteristics, their speaking rates and styles, their facial expressions, the precision with which they articulate words, their stress and intonation patterns, and their dialects and accents (see section 4.4). In addition, talkers are perceived in variable conditions (e.g. levels of light and noise in the environment), and yet audiovisual speech perception is extremely robust and adaptive: people are able to perceive and understand speech despite its enormous variability (e.g. Johnson & Mullennix 1997).

3.6 How do perceivers cope with the variability in speech production?

In auditory speech perception, the term ‘normalization’¹³ has been used to describe the remarkable perceptual and cognitive ability to cope with the variability in speech stimuli (Halle 1985). The majority of the work in this area has been on auditory speech perception, but following Yakel and colleagues’ (2000) example, the term is borrowed here to consider how speechreaders ‘normalize’ visual speech stimuli.

There is empirical evidence to support the suggestion that words that are phonologically similar may be activated concurrently in auditory word recognition (e.g. Luce & Pisoni 1998; Marslen-Wilson & Warren 1994). The assumption that phonological information is also extracted and used to identify the phonological-lexical representation that best fits it in visual speech recognition (see e.g. Andersson 2001) suggests that there is a *phonological* prelexical level of processing involved in speechread word recognition. This is supported empirically by Mattys and colleagues (2002) who found that, for both deaf and hearing adults, visually perceived spoken words are recognized in the context of words that are perceptually similar to them. In models that include a level of phonological prelexical processing, stimulus variability is assumed to be an undesirable source of noise in the speech signal. The abstract, idealized, underlying features of speech (phonemes), are assumed to be the true objects of perceptual analysis. Normalization, in this context, is the process that converts physically different tokens into standardised representations of some kind (Pisoni 1997). It is assumed to involve a loss of information, and as a consequence, a reduction in stimulus variability: “talker attributes are extracted and discarded,

¹³ ‘*Normalization*: Reduction to a normal or standard state’ (definition from Webster’s New Twentieth Century Dictionary, 1983).

leaving the phonetic material needed for the perception of speech segments” (Yakel et al. 2000, pg. 1405). The assumption that there is a (phonological) prelexical level of representation is arguable, however. The extreme positions in the debate concerning a possible prelexical level of representation are not able to account for all of the empirical data, and are therefore no longer tenable (McQueen & Cutler 2001). Those arguing for an episodic account of the lexicon, with no prelexical abstract representations, do not account for data that demonstrate abstraction (e.g. vowel epenthesis in Japanese, Dupoux et al. 2001) and normalization (e.g. Halle 1985; Johnson 1990). Equally, those arguing for prelexical representations (phonemic, syllabic or feature-based) do not account for data showing that listeners are able to remember the fine detail associated with particular utterances of particular words (e.g. Goldinger 1998; Pisoni 1997; and with regards to speechreading specifically, Yakel et al. 2000). It seems likely then that a contemporary conceptualisation of spoken word recognition should involve both episodic and abstractionist components (Hawkins 2003; McQueen & Cutler 2001). Accordingly, there is an assumption here of the existence of prelexical representations, but it is not assumed that episodic information is discarded.

There is evidence now to suggest that what a listener learns about a talker’s voice (Pisoni 1997), or a speechreader about a talker’s facial information (Yakel et al. 2000) is not discarded, but is encoded and subsequently used to facilitate a phonetic interpretation of the linguistic content of the message. For example, in auditory speech perception, word identification performance across three signal-to-noise ratios was found to be better for words produced by a single talker than when the same words were produced by 15 different talkers (Mullennix et al. 1989). In addition, exposure to a talker’s voice has been found to facilitate subsequent perceptual processing of novel words and sentences spoken by the same talker (Nygaard et al. 1994; Nygaard & Pisoni 1995), and experiments on the serial recall of lists of spoken words have demonstrated that specific details of a talker’s voice are encoded into long-term memory (Goldinger et al. 1991; Martin et al. 1989). The finding of mutual interference in a speeded classification task in which subjects were required to attend selectively to one stimulus dimension (e.g. phoneme) and ignore the other dimension (e.g. voice), suggests that the two perceptual dimensions (phoneme and voice) are not processed separately (Mullennix & Pisoni 1990). The pattern of interference was asymmetrical: it was easier for the subjects to ignore irrelevant phoneme variation

when their task was to classify the voice than it was for them to ignore the voice dimension when they had to classify the phoneme.

This evidence suggests that the neural representation of spoken words and sentences encompasses both a symbolic description of the utterance in terms of phonetic representation, and additional information about the structural description of the source characteristics of the specific talker. The talker-specific information could be retained in a 'procedural' memory system; this would increase the efficiency of the perceptual analysis of new words produced by the same talker because a detailed analysis of that talker's speaking characteristics would not have to be performed again. Alternatively, exemplars of each individual talker's speaking characteristics could be stored in a composite memory system and then retrieved during the process of word recognition when new tokens from a familiar talker are encountered (Pisoni 1997).

Analogously, in visual speech perception, sentence identification performance (on the BKB sentences) has been found to be better for sentences produced by a single talker than when the same sentences were produced by 10 different talkers (Yakel et al. 2000). This is unlikely to have been due to a superficial stimulus change because there was no difference in speechreading performance between sentence lists viewed with a single colour tint and those viewed with mixed colours. In addition, it has long been known that people are able to speechread sentences more accurately when the talker is familiar to them than they are watching a stranger (see e.g. Day et al. 1928), and people have been found to be faster at speeded vowel classification from static photographs when they were personally familiar with the faces portrayed (Schweinberger & Soukup 1998; but see Campbell et al. 1996).

What aspects, then, of a talker's facial information and speaking style facilitate the extraction of phonetic material? Voice (see above) and speaking rate (Nygaard et al. 1995; Sommers et al. 1994) effect auditory speech perception (variability interferes with perception, and constancy facilitates it), but amplitude does not. Listeners encode information about a talker's vocal tract transfer function and how it changes over time, and use this information when they have to process the linguistic attributes of the signal (Pisoni 1997). In visual speech perception, therefore, speechreaders may encode information about a talker's articulatory patterns (rather than simple facial feature information; Saldana et al. 1996) with the phonetic information. Far from

being discarded at a very early stage of processing, time-varying (as opposed to time-independent, see section 3.4.i) talker-specific information may be retained for some time to facilitate speech recognition. Retaining such features when stimuli are presented by several different talkers incurs a greater processing cost than it does for a single talker, and the features from one talker could potentially produce interference when a different talker is perceived.

Perceptual learning of voices is both talker- and task-specific (Nygaard & Pisoni 1995), which suggests that attention is directed to becoming familiar only with the talker-specific attributes that are relevant for the task in hand. In addition to producing interference, presumably, retention of talker-specific features would enhance performance on subsequent trials with the same talker, and could be one reason for the marked practice effect seen in speechreading (see e.g. Dancer et al. 1994). A logical extension of this, which may explain the decrease in speechreading performance for an unfamiliar accent, would be that the greater the difference between the speech input and speech that is familiar to the speechreader, the greater the demand on the cognitive resources needed for ‘normalization’ (referring here to extracting the phonetically relevant features, not discarding the other features).

If a talker’s speech is remembered in a form that gives access to exemplar memory for at least some aspects of it (Hawkins 2003), then a variety of information could be extracted from it that could facilitate speechreading. In addition to segmental information (“I know that this talker realises his/her phonemes in this particular way, so now I can recognise them more easily”), for example, talker-specific information could provide information about the emotive content of the spoken message (familiarity with the talker’s facial expressions, degree of expressiveness, etc).

In their experiments with audio-visual speech, Sheffert and Fowler (1995) found no visual speech priming/facilitation, that is, no evidence of visual normalization, but did find robust auditory priming/normalization. On the other hand, for silent, visual-only, speech, Yakel (2000) found evidence of visual normalization. It is possible that adults who are deaf, and who are therefore used to perceiving speech virtually visually-only, with very little useful auditory input, may be better at ‘normalizing’ it – at extracting the phonological / linguistically useful information, and at using the talker-specific information. Hearing people may normally rely on the auditory phonological information and may not extract the visual talker-specific information to

the same degree. These skills may contribute to the variability in speechreading skill in both deaf and hearing people: good speechreading may reflect more efficient ‘normalization’.

3.7 How is speechread information processed and stored in working memory?

Working memory has been considered a critical information-processing component of speechreading for many years (e.g. Kitson 1915; Lyxell & Rönnberg 1993; Rönnberg 1995), and is central to Rönnberg and colleagues’ conceptualisations of speechreading (the working memory model for poorly specified language input, Rönnberg et al. 1998). Proficient speechreading requires the efficient processing and storage of the perceived information in working memory (Lyxell & Rönnberg 1993). Rönnberg and colleagues (1998) describe these two functions of working memory in speechreading (processing and storage) as representing “two sides of the same coin” (pg. 105) since both are essential. In this section, the role of working memory in speechreading will be considered with reference to Baddeley and Hitch’s influential multi-component working memory model (1974; see Baddeley 1986; 1990; 1997; 2000 for revisions), and then the differences between working memory in deaf and hearing people will be considered.

3.7.i What are the roles of working memory in speechreading?

The working memory model (Baddeley & Hitch 1974; Baddeley 1986; 1990; 1997; 2000) is made up of four components: an attentional control system, termed the *central executive*, two subsidiary slave components, the *phonological loop* (originally called the ‘articulatory loop’) and the *visuo-spatial sketchpad*, and a limited-capacity temporary storage system, the *episodic buffer* (added by Baddeley in 2000). The phonological loop is specialised in processing and storing verbal information, and is generally considered best suited for processing and retaining consecutively encountered linguistic information units (Baddeley 1986; Liberman 1992). It is composed of two parts: a temporary phonological store where verbal material is stored by means of a phonological code which decays after approximately one and a half to two seconds, and an articulatory control process, which serves to refresh the decaying codes through rehearsal. The non-linguistic visuo-spatial sketchpad, on the other hand, is specialized for the retention of the visual structure of objects, as well as the spatial relations between different objects or among parts of the same object. Logie (1995) proposed that the visuo-spatial sketchpad might comprise a visual cache

to store visual information, and an inner scribe to rehearse this information and to be involved in planning movement. The episodic buffer (Baddeley 2000) integrates information from a variety of sources, serving as an interface between systems that involve different sets of codes. It is controlled by the central executive, and can be accessed through conscious awareness.

In comparison to audio-visual speech perception with normal hearing, speechreading is cognitively difficult and effort-demanding, and makes heavy demands on on-line processing. For example adults appear to rely to a considerable extent on processes of automatic lexical activation and competition in audiovisual speech processing, and exploit additional sources of information that point to possible locations of word boundaries (see section 3.2). The impoverished speech signal available to the speechreader, however, makes segmenting it a particularly difficult task implying that, for speechreaders (deaf or hearing), lexical activation may not be automatic, and may make heavy demands on the attention and executive functions of the working memory system (that is, the functioning of the central executive).

Visually perceived speech, even in the absence of auditory information, is sequential, linguistic information, and is best processed as such in the phonological loop, rather than as visuo-spatial information. The efficient functioning of the phonological loop is therefore considered crucial to the efficient processing of spoken and written language. The working memory model postulates that auditory speech information gains direct access to the phonological store, whereas written material must first be recoded by the articulatory process into a phonological code in order to be retained in the store (Baddeley 1997). Campbell and Dodd (1980; 1982) showed that visually perceived speech inputs can also access the phonological store directly: speechread material is remembered as if it had been heard, rather than as if it had been recoded like read material. However, this direct access for speechread material assumes that it *is* processed using a phonological code (which may not be the case for all deaf people, see section 3.7.ii).

Given these fundamental roles of working memory in speechreading, it is unsurprising that high working memory capacity has been identified as a key feature in individual cases of exceptional speechreading skill (Lyxell 1994; the case of SJ; Rönnberg et al. 1999; the case of MM), audio-visual speech comprehension (Rönnberg et al. 1995; the case of MJ, cited by Lyxell et al. 1996), and in tactually supported speechreading (Rönnberg 1993; the case of GS). Working memory may

also effect speechreading indirectly: it been shown to be related to language learning skills in hearing children, such as the ability to learn English syntactic rules (Daneman & Carpenter 1980) and to recognise and understand new words (Gathercole et al. 1997; Gupta & MacWhinney 1997). It has also been found to correlate with spoken word recognition in deaf children following cochlear implantation (Pisoni & Cleary 2003; Pisoni & Geers 2000), and with reading in hearing (Mann et al. 1980; Shankweiler et al. 1979) and deaf children (Blair 1957; Watson et al. 1982).

3.7.ii How does working memory differ in deaf and hearing people?

There have been many studies concerning working memory in deaf people over the last century: as Marschark and Mayer (1998) observed, ‘memory’ has been perhaps the single most dominant research theme concerning deaf people in that time. The central cognitive components of the working memory of deaf people have been shown to function as efficiently as those of hearing people (Lichtenstein 1998), although their development is delayed (MacSweeney 1998). However, a plethora of studies over many years have shown that deaf children and adults tend to have shorter memory spans and perform less well in other short-term memory tasks than their hearing peers (e.g. Bellugi et al. 1975; Belmont & Karchmer 1978; Blair 1957; Hanson 1982; Kyle 1980b; Lichtenstein 1998; Pintner & Patterson 1917; Wallace & Corballis 1973). It has generally been agreed that this reflects deficient verbal coding: deaf individuals are not able to make efficient use of the phonological loop as hearing people do. Evidence suggests that even intensive oral training does not equip most deaf people with a robust, reliable inner speech code equivalent to that of hearing people and suitable for processing spoken language (Campbell & Wright 1988; Hanson & MacGarr 1989; Miller 1997). This is not surprising since the phonological loop “is assumed to have developed on the basis of processes initially evolved for speech perception (the phonological store) and production (the articulatory rehearsal component)” (Baddeley 2000, pg. 419), and these are delayed in the development of deaf children (see Chapter 2, Section E). The fact that so many spoken words are similar from the speechreading point of view (see section 3.3) makes it likely that the phonological processes involved in verbal working memory may be relatively weak or unreliable when speech has been learned through speechreading alone. Hanson (1982) showed that the modality of the stimulus effects the type of memory code used by deaf people. A speech-based (phonological) code would therefore be expected to

be used in speechreading, since it is visually perceived *speech*. However, some deaf individuals, particularly those who prefer to communicate manually, may alternatively or additionally, make use of visual coding (Blair 1957) or a sign-based code (Shand 1982) in storing spoken material. Visual coding is used by young hearing children, but gradually replaced by phonological coding, such that the latter is used almost exclusively by around the age of ten. Since many deaf people do not develop an efficient phonological code, they may continue to use visual coding. Several researchers have shown positive correlations between visual sequential memory and speechreading that may support this suggestion (Costello 1957; De Filippo 1982; Neyhus & Myklebust 1969; Risberg & Agelfors 1978; Sharp 1972). De Filippo (1982), for example, investigated the contribution of memory for mouth shape sequences to speechreading performance, and found that the visual memory factor was predictive of speechreading skill. Alternatively, deaf speechreaders with strong BSL skills may use a sign-based code. The structure of working memory for sign language has been shown to be similar in many respects to working memory for spoken language (Wilson 2001; Wilson & Emmorey 1997; 1998), suggesting that it develops in response to language input regardless of the modality, resulting in largely the same architecture across signed and spoken languages. However, evidence also suggests that there are some important differences between working memory for signs and for speech based on the differing information-processing capabilities of the visual and auditory modalities (e.g. Wilson et al. 1997; Wilson et al. 2003). Wilson and Emmorey (2003) suggest that the sign-based rehearsal system observed in deaf signers “may be a specialized usage of working memory components that exist in the hearing population as well and are used for general purposes of visual representation” (pg. 102).

Since neither visuo-spatial coding nor sign-based coding are as well suited to the sequential linguistic nature of speech as phonological coding, their use may have a negative impact on speechreading ability.

3.8 Is phonological coding the same in deaf and hearing people?

Congenital deafness prevents the development of well-defined phonological representations. An *acquired* hearing loss is enough to initiate a process of phonological deterioration and this deterioration continues as a function of the duration of deafness (Andersson & Lyxell 1998). Individuals who have been deaf

since birth are therefore unlikely to have lexical-phonological representations like those of hearing adults (see section 2.21). It is not, however, impossible for deaf people to develop such representations. Cued speech, a visuomanual language input that is fully specified at the syllabic and phonemic levels (Leybaert & Alegria 2003; see sections 2.11 and 2.21), substantially improves speech processing in children who have been exposed to it extensively from very early childhood (Alegria et al. 1999; Leybaert et al. 1998; Nicholls & Ling 1982; Périer et al. 1988), enabling users to develop phonological representations that can be used, for example, in rhyme judgements (Charlier & Leybaert 2000), rhyme generation (LaSasso et al. 2003), and reading and spelling (Alegria 2003; Leybaert 2000). Deaf individuals who do not use cued speech have also been shown to be able to perform phonological awareness tasks at an above chance level (e.g. Campbell & Wright 1988; Dyer et al. 2003; Hanson & Fowler 1987; see section 2.21), and to show evidence of using speechread information to perform phonological awareness tasks (Dodd & Hermelin 1977). The phonological awareness skills that do develop in deaf people may, then, reflect a different balance of knowledge than in hearing people: they may reflect distinctions that are specific to speechreading. Phonological representations are derived from all of the available information about the contrastive units of spoken language: auditory, visual and kinaesthetic. Given the importance of dynamic information in speechreading (see section 3.4.i), knowledge about articulatory movements seems particularly likely to be encoded, perhaps with knowledge about the kinaesthetic sensations associated with speech production, rather than the emphasis on auditory ‘speech sound’ information that the term ‘phonemic’ typically implies (see section 2.21). Because non-auditory information (such as visual or kinaesthetic information about speech) cannot fully reflect all of the phonemic aspects of spoken language (Campbell & Wright 1988), deaf people’s representations of the language-specific mappings between speech patterns and meaningful linguistic elements in long-term memory are likely to be less well-specified, and/or different from those of hearing individuals.

So far this chapter has focused on the perception and processing of the visually perceived speech signal, that is, on ‘bottom-up’ processing. However, comprehension of a spoken message (speechread or otherwise) is also influenced by information that is not directly available in the speech signal, through ‘top-down’ processing.

3.9 What is the role of top-down processing?

“Perhaps the most fundamental issue in language comprehension is understanding how “top-down” knowledge, not provided by the relevant aspect of the stimulus, is accessed and used” (Garrod & Pickering 1999, pg. 3)

The role of top-down information, or context, in speech processing has been hotly debated, particularly between theorists with interactionist and autonomous positions. Context refers to all of the information that is not in the speech signal at any given moment. It can include previous information from the speech signal, linguistic knowledge (phonological, lexical, syntactic, semantic and/or pragmatic), extra-linguistic information, and world knowledge.

The provision of contextual cues is known to enhance speechreading performance among adults with normal language competencies (Garstecki & O'Neill 1980; Sanders 1982; Stoker & French-St George 1984), and among adults with acquired hearing losses (Pelson & Prather 1974). This includes linguistic contextual cues in the form of phonological, lexical, syntactic, semantic, pragmatic, and topical constraints (Boothroyd 1988; Haas 1982; Hanin 1988; Summerfield 1983). However, the extent to which different individuals make use of top-down information may vary according to their language and speechreading skills and strategies. Historically in the speechreading literature, processes have been divided into ‘analytic’ (bottom-up) and ‘synthetic’ (top-down), and there has been disagreement about which drive speechreading. Because the visual speech signal is impoverished, it has been proposed that skilled speechreaders make use of higher-level information such as topical context to *facilitate* lexical identification, and to disambiguate the message. Poorer speechreaders, on the other hand, may attempt to recognise each phoneme while failing to utilise contextual cues (see e.g. Williams 1982). In contrast, there is the argument (paralleled in the reading literature - see e.g. Stanovich 1980) that, for skilled speechreaders, speech recognition is driven by word identification skills which subsequently activate higher level information. Poorer speechreaders rely on semantic and syntactic expectancy-based processing, and/or on situational and paralinguistic cues, due to their inadequate word identification skills. Expert speechreaders, on the other hand, have fast and automatic word recognition and rely less on higher-level sources of information. The assumption in the majority of bottom-up models of spoken word recognition is that, following recognition, information such as the word’s meaning is made available to higher-level

psycholinguistic processes (Tyler and Frauenfelder 1987): top-down information is therefore only accessed post-recognition.

Not all speechreaders are equally predisposed to benefit from top-down cues (Garstecki 1976; Hanin 1988). The ability to predict words is highly dependent on an individual's linguistic background and their ability to use the redundancy, content, and grammatical rules of language to, for example, complete a sentence (Giolas et al. 1970). Individuals who are hearing may therefore be expected to be better able to use linguistic contextual cues than those who are deaf since they are expected to have better knowledge of spoken language. This is also true of contextual cues that are dependent on world knowledge, since hearing individuals may be expected to have developed wider world knowledge (Boothroyd 1988). Deaf adults, on the other hand, may be particularly adept at using top-down cues from the environment or talker to disambiguate the perceived segmental information. Profoundly deaf adults use speechreading to varying degrees in their everyday lives to access the spoken language of the majority community in which they live. In such everyday situations they speechread not to identify each word (or, more extremely, each phoneme), but to understand the message of the talker. Given that the talker is not often likely to be directly facing them in a non-distracting room with ideal lighting conditions, the deaf speechreader may become adept at perceiving all available contextual and paralinguistic clues (e.g. situation, gesture, affect) to supplement the degraded segmental information. Such clues are severely reduced in controlled assessment situations, but skilled deaf speechreaders may use those that remain. For example, facial changes such as eyebrow raises and/or head nods that may indicate sentence focus. They may also have more awareness of the need to make use of their available stored knowledge to infer missing information (i.e. verbal inference-making, cf. Lyxell & Rönnberg 1987; Lyxell & Rönnberg 1989).

Given that the development of the skills and knowledge involved in both bottom-up and top-down processing is interdependent (see Chapter 2), it may be that speechreaders who are particularly skilled at bottom-up processes (such as normalization, see section 3.6) are also skilled at top-down processes. The key to effective, efficient speechreading may be cognitive flexibility in capitalizing on all available information – especially since the same attributes of the speech signal contribute to many different abstractions (Hawkins 2003). For example, vowel

duration in a particular utterance can contribute to percepts of prosody, lexical form, and information about the talker's state of mind.

3.10 Summary and conclusions

This chapter has reviewed the literature concerning visual and auditory-visual speech processing in profoundly congenitally deaf and hearing adults. The principal conclusions are summarised below:

- Word onsets (the richest and least variant parts of words) and, especially, prosodic (stress-based) cues are expected to be particularly useful in the visual segmentation of the speech stream.
- A reduced proportion of phonemes can be perceived visually in comparison to auditory or auditory-visual perception. However, since relatively few words in English have close neighbours in (phonologically defined) lexical space, a relatively large proportion of English words may be identified on the basis of their visemic properties.
- Stressed vowels can be identified with good accuracy under optimal conditions.
- Some (deaf) speechreaders have been found to be able to distinguish between words that are usually considered homophonous.
- Time-varying (dynamic) information may play a relatively greater role in visual speech perception than time-independent (static) information.
- Both oral and extra-oral facial movements may be important in speechreading.
- The speech gesture is a likely object of perception. This further suggests that the movement of speech (as opposed to static features) may be important in speechreading,
- A talker's facial information, and particularly their idiosyncratic articulation patterns, may be encoded along with segmental speech information, and used to facilitate a phonetic interpretation of the linguistic content of the speechread message.
- Speechread information is best processed in the phonological loop and makes comparatively heavy demands on the attention and executive functions of working memory.
- Deaf people are expected to have less efficient working memory for speech information, and may additionally make use of visual or sign-based coding.

- The phonological coding and representations of deaf people may reflect a different balance of knowledge than in hearing people: they may be based on visual and/or kinaesthetic speech information rather than being dominated by acoustic information.
- The use of contextual information (i.e. everything that is not being processed online in the speech signal; top-down processing) facilitates the decoding of a speechread message. The key to effective, efficient speechreading may lie in cognitive flexibility in capitalizing on all available information.

Chapter 4

TEST DEVELOPMENT I:

INITIAL DEVELOPMENT OF THE TEST OF ADULT SPEECHREADING (TAS)

4.1 Introduction

This chapter describes the initial development of the speechreading assessment battery used in this thesis: the Test of Adult Speechreading (TAS). The validity of any investigation of speechreading is dependent on the speechreading assessment(s) used. One reason for the variability found in the results of previous speechreading research lies in the wide variety of speechreading tests used (see Appendix A), many of which were not designed for that purpose.

In 1999 the need was identified for a new speechreading test that would be suitable for assessing the speechreading skills of deaf and hearing British adults at different linguistic levels. Following a review of extant speechreading assessments, test development began with the construction of the first, video-based, version of the Test of Adult Speechreading (TAS) (Ellis 1999; Ellis et al. 2001). This version was modified and digitised following pilot testing, and additional subtests were added to the core subtests. These latter stages of test development will be described in Chapters 5 (further development of the core subtests) and 7 (additional subtests).

This chapter consists of two sections:

- A. An overview of extant speechreading assessments with the aim of establishing what a new speechreading assessment should comprise.
- B. A description of the development of the initial, video version of the TAS.

Details of the existing speechreading assessments discussed in Section A, and of other examples of tests that have been developed or adapted previously to assess speechreading, are presented in Appendix A. The list of tests included is not exhaustive, but it demonstrates the variety of approaches taken in assessing speechreading, and gives an overview of the history of speechreading tests.

Section A: Overview of Speechreading Assessments

“I have come to the conclusion that there are no certain lipreading tests which can be used to give exact results in determining the pupil’s skill in reading the lips.” (Nitchie 1917, pg. 222)

Why develop a new speechreading assessment, and what should it comprise?

4.2 Objectives of a Test of Speechreading

Speechreading tests are required to measure the basic speechreading ability of an individual relative to the abilities of others. Reflecting the different definitions of speechreading (see section 1.2), such tests can be presented visually alone (without the auditory signal), in noise, or audiovisually for individuals with a hearing loss. In addition to research purposes, test results may be used for planning and evaluating intervention, evaluating rehabilitation aids, and exchanging reliable, meaningful information about the abilities of an individual or group between interested parties (Ijsseldijk 1988; Markides 1980; Markides 1989b).

A few assessments, such as the Revised CID Everyday Sentence Lists (Harris et al. 1961), have been used in a number of studies, and the CUNY sentences (Boothroyd et al. 1985) are used widely in clinical settings. However, no test has yet been generally accepted in Britain. The need for the development of a valid and reliable speechreading test, or battery of tests, expressed by a number of authors at the end of the 1980s (e.g. Ijsseldijk 1988; Markides 1989b; Montgomery & Demorest 1988; Silverman & Kricos 1990) continues.

The specific criteria for the speechreading assessment described in this thesis were that it should:

- Be suitable for use with both profoundly congenitally deaf and hearing British adults.
- Comprise different linguistic levels to explore patterns of speechreading abilities.
- Be suitable for use in investigating the relationship between literacy and speechreading ability.
- Be relatively quick to administer (about 20 minutes) so that it maintains the motivation of the testee, and could reasonably be included in a battery of behavioural tests.

As the following sections, and Appendix A, show, none of the available tests were suitable for use here, necessitating the development of a new assessment. The test format decisions for this new test were informed by a review of extant speechreading tests, outlined below under the following headings:

- Test materials
- Talkers
- Manner of presentation
- Manner of response & scoring

4.3 Test Materials

A variety of test materials have been used in existing speechreading tests. These include phonemes, nonsense syllables, words, proverbs, sentences, questions, short stories, instructions, and passages from a book. Some researchers have claimed on a priori grounds that only one type of material measures ‘true’ speechreading ability. For example, Brannon and Kodman (1959) and Sudman and Berger (1971) advocated the use of single words because they are free from contamination by syntactic or pragmatic information. In contrast, other researchers (e.g. McCormick 1979; Pelson & Prather 1974; Sanders & Coscarelli 1970) advocated conversational interaction because only then are all the dimensions of speechreading included. The majority of researchers have accepted for many years that different test materials assess different aspects of speechreading skill (see e.g. Clouser 1977; Erber 1977). Ideally, speechreading assessment materials should include a number of linguistic levels that present a range of difficulties for the speechreader. These limit ceiling and floor effects and give a more accurate picture of testees’ speechreading abilities (Jackson 1988; Spitzer et al. 1987). In addition, the use of different types of assessment materials comprising different linguistic levels can shed light on the various processes involved in speechreading (Gailey 1987). The use of nonsense syllables, single words, sentences and connected speech in speechreading assessments are reviewed below.

4.3.i Nonsense syllables

“A test with sounds pronounced individually by themselves, apart from any connection in words, is no real test of lip-reading skill” (Nitchie 1917, pg. 223)

Many tests consist of, or include, nonsense syllables. As materials in a test designed to assess functional speechreading, these have low face validity: in everyday conversation people try to decode meaningful speech, not nonsense syllables. Further, performance on nonsense syllables does not predict an individual's speechreading proficiency on other materials (Bernstein et al. 1998a), and the visibility of the phonemes that make up words and sentences have not been found to predict the difficulty of those words (Hipskind et al. 1973) or sentences (Clouser 1977) as speechreading stimuli. Phoneme identification, then, makes up at best a subset of the mental events that result in word identification (Bernstein & Auer 1996). Speech perception does not necessitate the isolation and decoding of each phoneme segment (Faulkner 2003). The high predictability of spoken messages means that a partial decoding of phoneme segments is usually sufficient since the imperfectly identified segments can be filled in.

In addition, there are indications that the speech motor control of simple nonsense syllables differs from that of meaningful utterances (Munhall & Vatikiotis-Bateson 1998). Munhall and Vatikiotis-Bateson found that the lip motions of nonsense utterances could be estimated slightly more accurately from the activity of eight perioral muscles than those of sentence utterances. However, the recovery of more remote facial locations (e.g. cheek motions) was much worse for nonsense utterances than for sentences. They interpret this finding as consistent with the absence of prosodic and other expressive details in over-simple, repetitive speech materials.

Nonsense syllables do enable testers to assess speechreaders' ability to decode speech sounds at the lowest, pre-lexical level, and thereby to attempt to determine the extent that these skills are used in speechreading materials at higher linguistic levels. However, the low face validity of isolated consonants, vowels and nonsense syllables, the lack of their predictive power, the motoric differences in their production, and the requirement of literacy in their assessment since they cannot be tested through picture-pointing (see section 4.6), led to the decision not to include this material type in the new Test of Adult Speechreading (TAS). The ability to discriminate between phonemes *within a word context* will be assessed with an additional subtest (see Chapter 7).

4.3.ii Words in isolation

“Word recognition deserves increased attention in efforts to understand speechreading” (Bernstein & Auer 1996)

The lexical unit (the word) is central to most models of audio-visual speech processing (e.g. Luce & Pisoni 1998; Marslen-Wilson 1987; McClelland & Elman 1986), and speechreading (e.g. Bernstein et al. 2000; see section 3.1). Typically in speechreading research, phonetic perception has been studied with the identification of phonemes in nonsense syllables, and the perception of connected discourse, with the identification of words in isolated sentences. This implies a theory that accounts for speechreading in terms of bottom-up phoneme perception (historically referred to as ‘analytical’ speech recognition skills), and top-down syntactic / semantic processes (‘synthetic’ skills). Word recognition is widely accepted as the critical interface between these levels of processing in auditory speech understanding research. When straightforward bottom-up mapping of phonetic to lexical representations is precluded by coarticulation and the reduced nature of connected speech, the speechreader must rely on word-level representations to facilitate perception. Indeed, lexical effects may be hypothesized to be particularly important in visually perceived speech, since they are most robust when bottom-up mapping is underdetermined (Samuel 1996). Lexical effects have been found in the perception of phonetically ambiguous, incomplete or distorted words in a variety of tasks (e.g. Ganong 1980; Marslen-Wilson & Welsh 1978; Segui & Frauenfelder 1986).

Rosen and Corcoran (1982) argue against the use of lists of single words as speechreading test material because they are not representative of everyday speech, and the results from such tasks are poor predictors of performance in more natural tasks (Green et al. 1981b). However, high associations have been found between the ability to speechread isolated words and words in sentences (in comparison to the, at best, low-to-moderate associations found between non-word phoneme identification, and the proportion of phonemes identified correctly in words or sentences). They are therefore likely to constitute a useful part of a speechreading test battery.

4.3.iii Sentences and connected speech

“A test in lip-reading can hardly be called complete without having incorporated in it a section for connected language ... a story of some sort is the only proper test for the phase of lip-reading which the student is called upon most frequently to experience” (Hilliard 1917).

In addition to single word stimuli, there is a need for speechreading assessment at levels above lexical recognition, that is, of the comprehension of sentences (which could not be scored by key word scoring) or of continuous speech (Dancer et al. 1987). Many tests focus on sentence-level stimuli (e.g. the BKB sentences, the CID everyday sentences), but the majority are scored on key words. The use of a multiple-choice response format (see section 4.6) can be used to enable testees to respond correctly if they understand the whole message, but not if they are able only to decode an isolated word in the sentence (although this would reduce the choice of likely pictures, increasing the chance of a correct response through guessing).

Developing assessment stimuli at the connected speech level has not proved to be an easy task. For example, Spitzer and colleagues (1987) used the Gold Rush Paragraph to test connected discourse. Participants saw the passage spoken, and then answered six questions about it. However, the authors concluded that the test was not suitable for testing connected speech: the passage was very poorly comprehended (mean score was 1.14 out of a possible maximum of 6) and the questions did not provide an adequate range of scores to differentiate speechreading abilities. Although difficult, assessing speechreading skills at this level is important because of the heavier demands made on segmentation and working memory functions, which are fundamental to functional speechreading (see Chapter 3).

Decision for the TAS: Three linguistic levels will be assessed in three subtests: single words, sentences, and connected speech (short stories).

The length of the test and the difficulty of the test materials need to be considered in addition to their linguistic level. These are particularly important because of their impact on testees' motivation and attention. Speechreading, in comparison to audio-visual speech perception with normal hearing, is cognitively difficult and effort-demanding, hence the relatively low levels of performance achieved on open-response tests (see e.g. Rönnberg et al. 1996; Samuelsson & Rönnberg 1993). Motivation impacts on speechreading accuracy (Berger 1972a; Lidestam 2002) by determining

how hard the speechreader tries to understand what is being said; that is, how and how well the speechreader utilises their perceptual and cognitive abilities. The attention and executive functions of the working memory system (see section 3.7) are likely to be essential in speechreading. Sustained concentration and fatigue are therefore likely to impact negatively on performance, as well as rendering the testing experience unpleasant for the testee. Arakawa and Furumaya (1962) present evidence of increased eye fatigue following a ten minute speechreading session. They measured eye-blink rate in junior high school deaf students before and after speechreading, and found that the rate was increased after speechreading. This effect was greater after speechreading than after reading. Test length and degree of difficulty are important in sustaining motivation and limiting fatigue.

4.3.iv Test length

Many extant tests, such as Utley's (1946) 'How well can you read lips?', which takes an hour and fifteen minutes, are too long for the testee to maintain optimum attention throughout (Upddike 1989) and are likely to induce fatigue. Additional considerations for the development of the TAS were the good will of the participants, and the intention to include the test in a battery of behavioural assessments. The participants' good will was essential for this and future research. An excessive amount of speechreading assessment may have discouraged many deaf adults, particularly the culturally Deaf, from participating. Ideally, therefore, a speechreading test should be as short as possible, while still being valid and reliable.

Decision for the TAS: A total test length of fifteen to twenty minutes was considered optimal for the new test: this is long enough to include different linguistic levels in a reliable test, but short enough to maintain testees' attention and motivation, and to be included in a behavioural test battery.

4.3.v Degree of difficulty

"Broken into its components, lipreading seems an almost impossible circus trick, like juggling Indian clubs while spinning a dinner plate on one's forehead." (Kisor 1990, pg. xii)

A speechreading test should yield reliable results, avoid floor and ceiling effects, and differentiate well between speechreaders (Bench et al. 1995). Many available tests, however, are excessively difficult, and therefore demoralising to complete. For

example, when Plant and colleagues' (1984) used 4 of the sentence lists (A, C, E and G) from the SPIN test (Kalikow et al. 1977) as a recorded speechreading test, their normally hearing participants achieved a mean score of only 7.96% (range 0-27%). DiCarlo and Kataja (1951) report that one of their deaf participants, an experienced speechreading teacher, refused to allow her pupils to see the Utley (1946) test because she felt it would destroy their self-confidence. The authors say of Utley's 'How Well Can You Read Lips?', "in addition to being a test of lipreading ability, the test seems to be one which tests the ability to tolerate frustration and persistent failure" (pg. 240). Furthermore, Calhoun and colleagues (1988) found that the revised Everyday Sentences (Harris et al. 1961) were more difficult than the Utley task for their normal-hearing participants. The BKB sentences (Bench et al. 1979) have also been found to be difficult: Daly and colleagues' (1996) hearing participants achieved mean scores ranging from 2.98 (0.06%) to 12.11(24.22%) key words correct (from a possible total of 50) depending on the talker. Before development of the new test began, a profoundly prelingually deaf male in his twenties, who uses speechreading effectively in his everyday life, was tested with a recording of the first 4 BKB sentence lists. His score was only 25% of the possible maximum, and he found the test demoralising to complete.

As with decisions about test length, the likely impact on participants' motivation and good will were important considerations. An excessively difficult test is likely to create floor effects, impact negatively on testees' motivation (thereby further reducing performance), and discourage individuals from further participation.

Decision for the TAS: the new test should be easier (and therefore more satisfying to complete) than many of the existing tests, with a mean total score of between 50% and 75%.

Different test materials have been found to be of different relative difficulties. For example, spondees¹⁴ have been found to be easier to speechread than trochees¹⁵, which are easier than monosyllables (Erber 1971). Monosyllables are easier to speechread than sentences (Erber & McMahan 1976; Green et al. 1981b), and shorter sentences are easier than longer ones (Boothroyd 1988; Clouser 1976a). Why should this be the case? Considering first the difference between single words and sentences:

¹⁴ Complex words consisting of two stressed syllables, e.g. 'hedgehog'

¹⁵ Two-syllable words in which the first syllable is stressed, and the second unstressed, e.g. 'squirrel'

when speechreaders are presented with single words in a speechreading test situation, they are presented with high quality tokens of citation-form speech. Word recognition for these items may be a (relatively) simple matter of bottom-up mapping between the visually perceived segmental (phonetic) and lexical representations. When speechreaders encounter fluent, connected speech, however, this kind of veridical bottom-up mapping may not be possible: segmentation of the speech stream is required, and the signal is degraded by reduction and phonological variation. With regards to test materials, this begins to be an issue for phrase- or sentence-length test materials, and the associated difficulties for the speechreader increase as utterance length increases. Considering the differences between word items as a function of their syllable structure: in all cases the speechreader is presented with citation-form speech, however, bisyllables have fewer neighbours, and more articulatory movement (see section 3.3.4.i). That spondees have been found to be easier than trochees is unsurprising since the former contain two stressed vowels. Vowels are comparatively easy to speechread (see section 3.3.ii) because they are reasonably well specified by the degree of vertical and horizontal lip separation and duration (Montgomery & Jackson 1983).

Decision for the TAS: The single word subtest was developed with monosyllables and spondees. The latter were included with the expectation that they would be amongst the easiest items in the test and would help to maintain the participants' motivation (particularly the poorer speechreaders).

4.4 The Talker(s)

"It must be admitted that the good Lord has created few people with legible countenances" (Calkins 1924, pg. 253).

Talkers differ in speechreadability (see section 3.6). This is not surprising when talker differences such as lip size and shape, speaking rate and rhythm, and the expressiveness of facial cues are considered. It follows, therefore, that the talkers(s) selected for a speechreading test will significantly affect the test results (Bench et al. 1995; Kricos & Lesner 1985; Lesner 1988). Test results should always be interpreted as specific to the talker(s) presenting the stimuli, since the number of viseme categories, or PECs (Auer & Bernstein 1997), produced by a talker can vary considerably in talkers judged as having normal articulation and auditory intelligibility (Jackson 1988; Kricos & Lesner 1982; Lesner & Kricos 1981; see

section 3.6). Talkers who have highly visible and distinctive speech produce the largest number of visemes (PECs) and yield the highest sentence perception scores. In addition, it should be noted that there is an interaction effect between the talker and speechreader in speechreading (Demorest & Bernstein 1992a; 1992b). That is, not all speechreaders find a specific talker equally difficult to speechread in comparison to other talkers. Thus, the judges that Bench and colleagues (1995) used to choose talkers for the BKB/A Speechreading Test tended towards agreement when ranking talkers, but did not agree perfectly. It is not therefore possible to select talkers such that there are consistent talker differences across speechreaders, or that they produce a certain number of viseme categories.

A number of talker-related considerations are discussed in this section: the number, gender, physical characteristics, dialect, and speaking style and rate of the talkers are discussed below.

4.4.i How many?

The majority of speechreading tests have used only one, arbitrarily chosen talker. A speechreading test can yield reliable results, and differentiate well between speechreaders while using only one talker. However, there are several arguments for using more than one (Bench et al. 1995):

1. A single talker may be atypical (see ‘characteristics’ section below), leading to a test result that is not representative of testees’ everyday speechreading ability;
2. Tests should, as far as possible, assess the general speechreading skill of an individual, not their ability to speechread a specific talker;
3. The use of a more than one talker increases the face validity of a test since speechreaders converse with a variety of people, and switch between talkers, in everyday life;
4. The use of more than one talker reduces the impact of the speechreader becoming increasingly attuned to the speaking style of an individual (see section 3.6).

Decision for the TAS: Two talkers were chosen to present the stimuli for the new test.

The number was limited to two because the test was to be reasonably short (see section 4.3.iv), and it was felt that too many talkers would become confusing and disruptive for the speechreader, making the test unnecessarily difficult. This concern has since been confirmed by Yakel and colleagues (2000), who found that

speechreading performance was significantly lower when there were ten talkers, and the talker thus changed from trial to trial, than when there was a single talker.

4.4.ii Gender

Individual differences in the speechreadability of both male and female talkers, and the interaction effect between the talkers and speechreaders make it difficult to reliably compare talkers on the basis of their gender. Aylesworth (1964) found no significant difference on a speechreading test as a result of talker gender. However, he used only four talkers (2 male and 2 female), and each speechreader saw only one of them. Daly and colleagues (1996), who used twelve Australian talkers (6 male and 6 female), did find a significant gender difference in talker speechreadability, with females being more easily speechread. This is consistent with findings that women are more successful communicators than men. For example, the former are more facially expressive (Buck et al. 1974). Hall (1984), in her review of research concerning gender differences in nonverbal communication, concluded that, overall, females are better encoders of nonverbal behaviour. Other contributing factors may include articulation, speed, and facial expression. Daly and colleagues (1996) showed that this gender difference can be apparent even within the speechreading test situation, which excludes many of the communication strategies (such as two-way interaction between a talker and speechreader) that would be expected to exhibit gender differences. The gender of talkers therefore needs to be considered, both in the interpretation of results from existing speechreading tests (the majority of which use only one talker), and in the development of new ones.

Decision of the TAS: It was decided to include one male and one female talker.

4.4.iii Physical characteristics

Speechreading is a demanding task, and it is therefore important to keep testees' motivation as high as possible (see pg. 113-114). Talkers should be acceptable to the testees, and not unusually difficult (and therefore demoralising) to speechread. To facilitate speechreading, the talkers' attire should not be distracting: their clothes should be plain and without jewellery. Men should be clean-shaven since, although findings concerning the effect of varying degrees of facial hair on speechreading have not been consistent, some deaf speechreaders have indicated that they found it distracting (Castle 1984; Kitano et al. 1985). Similarly, women should wear no make-up since lipstick has also been reported as a distracting element (DiCarlo & Kataja

1951). Other personal characteristics that have been cited as conducive to speechreading include thin lips as opposed to thicker ones (Berger et al. 1977), no deformation of teeth, lips, or jaw (Witter-Merithew & Siple 1985), and an expressive face and emotive ability (Jacobs 1982).

Decision of the TAS: The talkers chosen to present the new test stimuli had no facial deformations, and wore plain clothes and no jewellery. The male talker was clean-shaven, and the female wore no make-up. They were not screened for lip thickness or expressiveness, but during piloting speechreaders reported finding them acceptable.

4.4.iv Dialect

Deaf people often comment on the difficulties they have in understanding different dialects (see e.g. Plant 1997). This may reflect the greater demand on cognitive resources required to ‘normalize’ an unfamiliar accent (see section 3.6). It is important that a speechreading test reflects speechreading skill, not familiarity with dialectical variations. It would therefore be inappropriate to use an American or Australian test with British testees: there are variations in vocabulary, colloquial expressions and usage patterns which may make the test materials unfamiliar to British adults. Dialect is also a potential problem within Britain because there are a range of regional dialects, and this is something that must be taken into consideration when analysing results from tests that have been standardised on video or digitally and presented to testees from different regions.

Decision of the TAS: Both of the talkers presenting the new test material are from the south of England, and neither have a strong regional accent.

4.4.v Speaking style

The Royal National Institute for the Deaf (RNID) advises talkers to speak clearly but naturally without exaggeration when speaking to people with a hearing loss (RNID 2004). Hardy’s (1970) and Oyer and Frankmann’s (1975) work support this advice: the former suggested that speechreading may be adversely affected by the use of ‘careless’ speech judged auditorially indistinct, and the latter concluded that a natural speaking style (rather than over-exaggeration) facilitates speechreading. However, Franks (1979) found that articulatory exaggeration enhanced the speechreading of sentences, although it had little effect on the speechreading of words, and reduced the visual recognition of consonants embedded in syllables.

DiCarlo and Kataja (1951) report that some of their deaf participants “complained that speakers failed to express themselves in a normal manner, and that smiling during the process of formulating the words created distorted articulation” (pg. 238). They also report that talkers should not move their heads while talking, and that message-related extra-facial gestures can aid speechreading (this is supported by Rönnberg et al. 1998), while non-message-related gestures may function as visual distracters.

4.4.vi Speaking rate

There have been contradictory findings related to rate of speech. For example, Black and colleagues (1963), Oyer and Frankmann (1975), and Ijsseldijk (1992) found that speech rate did not influence speechreading performance. However, Frisner and Bernero (1958) found that profoundly deaf college students obtained higher speechreading scores on a filmed sentence test presented at a slower-than-normal rate. Dicarlo and Kataja (1951) state that many of their deaf participants criticised the rapidity of the speech in the Utley (1946) film, and Berger (1972b) reports that deaf adults prefer a slower than average speech rate. People who use speechreading consciously in their daily lives experience, and can tolerate, a wide variety of speech rates, but there is evidence that it can be a significant factor, and that, at least for some speechreaders, a slower than normal rate is optimum. One reason for this may be that the increase in meaningful pauses in slower speech provides important cues for speechreaders (Jacobs 1982).

Decisions for the TAS: The talkers producing the stimuli for the new test were instructed to speak naturally but clearly ‘as if talking to a child’ to encourage a slightly slowed but natural speech rate, and to look directly into the camera. They were not instructed specifically about their facial expressions, and were comfortable speaking to a camera, so expressed themselves normally. Multiple samples of each item were recorded and any featuring distracting smiles, or eye or head movements were discarded.

4.5 Manner of Presentation

4.5.i Live or Recorded?

The use of live voice testing has the obvious advantage of not requiring any special equipment. It is more similar to the speechreading people do everyday than a recorded version, and could therefore be argued to have greater face validity. The talker in a live, face-to-face test can also control the face-directedness of the testees, is likely to be more motivating (Ijsseldijk 1988), and can be chosen to have the same regional accent as the testees. However, the talker(s) may have considerable difficulty in repeating the same material many times in exactly the same way (Berger 1972b), and in producing voiceless speech in a natural way. For example, Fulton (1964) found that in a live situation the talker without voice starts to overarticulate. Where the test is used in more than one geographical area, it may be necessary to use different talkers for some testees, reducing the reliability of the test.

Recording the test materials overcomes many of the problems inherent in face-to-face tests without necessarily causing a significant difference from scores obtained through live presentation (Elphick 1984; McCormick 1980). The television image is very widely accepted and of high quality, and recording the test material allows variables such as lighting and image size to be controlled and kept constant from testee to testee. Talker errors can be eliminated, the rate of presentation controlled, and the sound removed without affecting the naturalness of the speech. Accordingly, the majority of the speechreading tests developed since 1980 have used video presentation. Dillon and Ching (1995) recommended that recorded tests be used “whenever reliable results are needed” (pg. 318).

The use of computer technology has all of the advantages of using recorded materials and more. It has been suggested as an appealing medium for speechreading testing and training for many years (see e.g. Montgomery & Demorest 1988). The combination of computer and video technology, such as laser videodisc and DVD (digital videodisc) has allowed new advances in testing such as the inclusion of interaction elements (see section 4.6.i) and computer stored and analysed responses. Computer-based test materials can also be manipulated easily as the need arises. For example, items can easily be omitted or added; the order can be altered or randomised; the image can be degraded, partially obscured, or altered in terms of colour or size; and any required sound (e.g. the auditory signal in or out of synchrony, or white noise) can be added and controlled. The necessary equipment is becoming

cheaper and increasingly available. However, when test development began the expense involved and the limited availability of the equipment needed (e.g. for clinicians and others who may wish to use a test) made it inappropriate.

Decisions for the TAS: The new test was initially recorded on video, and during later development digitised for administration via a laptop computer.

4.5.ii Audio-Visual or Vision Alone?

Whether to present the test with or without sound depends on what the test is being used to measure. If the objective is to assess visual-alone speechreading, participants are tested without sound. However, if the aim is the assessment of audio-visual language comprehension, the stimuli are presented with sound, and participants allowed to use residual hearing and hearing aids. In this case the validity of a test presented without sound would be questionable (Ijsseldijk 1988). However, it is difficult to assess the benefits individuals derive from their residual hearing (Conrad 1979) and testing in a visual only mode is therefore the only way of determining the effect of vision alone in the reception of speech (Sanders 1982). If a test is recorded with sound, it can then be used in either condition, or to compare the two conditions (see for example Donnelly & Marshall's (1967) description of the early use of Lowell and Taaffe's (1957) 'Film Test of Lipreading', pg.565-566).

Decisions for the TAS: The new test was recorded with sound, but administered silently.

4.5.iii Distance and Visibility

Erber (1971) found the effect of distance on word intelligibility to be significant. The speechreading scores of the orally educated profoundly prelingually deaf children in his study decreased by 0.8% per foot with increasing distance within the range 5-70 feet. Erber attributes this to the increased articulatory detail participants could see within the mouth of the talker when they were closer to her (his participants were aided by extra illumination at the mouth level of the talker).

Ijsseldijk (1992) found no effect of the amount of the talker visible when comparing the face, lips only, and two-thirds profile. Larr (1959), however, found that his participants found it easier to speechread with the talker's head and neck visible than with head only, lips only, or upper torso. Speech information can be provided by more peripheral areas of the face as well as by the lips (Munhall & Vatikiotis-Bateson

1998; see section 3.4.ii), and it is therefore important that all of the talker's face should be available to a speechreader. A full-body image could be argued to have higher face validity, since in everyday communication the speechreader is able to make use of additional cues from the talker's gestures (DiCarlo & Kataja 1951; Rönnberg et al. 1998). However, recording the talkers in a full-body view would have greatly decreased the size of the image of the face on the screen, which would have increased the level of difficulty in a manner similar to increasing the distance between the talker and the speechreader.

Decisions for the TAS: The talkers for the new test were recorded in a head and shoulders image so that they would appear approximately life-size on a screen. Initial testees were seated approximately two meters from the television screen on which the test was administered. After further development, testees were positioned at a comfortable distance from the laptop computer's screen so that they could use the mouse to make their responses.

4.6 Manner of Response and Scoring

The majority of available speechreading tests use a repetition response (written or spoken). Elphick (1996) claims that "the only sure way of knowing if recipients have decoded speechreading correctly is to ask them to repeat the items given" (pg. 359). However, this presents the problems of spelling, handwriting difficulties and time, in the case of a written response, and the intelligibility of the speech of deaf testees in the case of an oral response. In addition, in everyday conversation people listen (and/or watch) for the gist of the message, not for the purpose of repeating every word (Tye-Murray et al. 1996).

Responding to simple questions (see e.g. the Danish HELEN test, Ewertsen 1973) circumvents many of these problems, since testees can respond in their preferred language, and are required to understand the message of the question in order to answer, not identify every word of it. However, this response is limited only to sentence level stimuli and could not therefore be used to compare performance on different types of speechreading stimuli.

A picture multiple-choice response mode (recommended by Ijsseldijk 1988, following a review of speechreading tests) allows testees to indicate that they have understood the message without involving literacy or expressive language skill. Donnelly & Marshall (1967) have shown that converting a written response test to a multiple-

choice test does not change the stability of the test. The latter is also less effort for participants, more neutral, and causes less frustration (Ijsseldijk 1988). The practice effect which results in increased scores when participants are retested (see e.g. Dancer et al. 1994) is less for closed-set response tests than for those with open-set material (Dillon & Ching 1995). In addition, a multiple-choice format enables the tester to coerce participants into making a response to every item, and is immediately correct or incorrect, which avoids the problem of scoring open response tasks (attempts to solve this problem have not been satisfactory - see e.g. Montgomery & Demorest 1988). However, key words (in a sentence-level test) and chance can have a much greater influence when participants respond with forced-choice pointing, and an unequivocal right or wrong answer does not present the opportunities for further qualitative interpretation that are available following a written or transcribed oral response.

Decision for the TAS: A picture-pointing multiple-choice response was chosen for the new test.

In some previous multiple-choice tests (e.g. Craig 1964) the possible responses for each item consist of a picture and a caption. Pictures alone were selected for the new test because the use of written language could give an advantage to good readers, and thus invalidate any correlation between speechreading as measured by the new test and a measure of literacy.

4.6.i Interaction

People interact with each other during the give and take of everyday conversation. When a breakdown occurs, an individual can ask his conversational partner to repeat or reword the message. The effectiveness of an individual's repair strategies influences the degree of success with which speechreading can be used in everyday conversation (see section 2.23). There is no measure of this skill in the majority of speechreading tests. Where repair options have been included (e.g. Tye-Murray et al. 1996), the most commonly used strategy has been found to be repetition (it was chosen more frequently than the other options of 'rephrase', 'elaborate', 'simplify', or 'key word'). However, the addition of a repeat option in the new test would increase the test length and scoring complexity.

Decision for the TAS: It was decided that each item of the test would be presented only once during the development and current use of the test, but that the option for repetition may be included at a later date for use with younger testees, or those with additional difficulties.

4.7 Summary of decisions about test development

It was decided that the new Test of Adult Speechreading (TAS) should:

- Consist of three linguistic levels, assessed in three subtests: single words (monosyllables and spondees), sentences, and connected speech (short stories);
- Take fifteen to twenty minutes to complete;
- Yield a mean total score of between 50% and 75%;
- Be spoken by two talkers from the south of England, one male (clean-shaven) and one female (no make-up), both with no facial deformations, wearing plain clothes and no jewellery;
- Be recorded with sound, with the talkers in a head and shoulders view, speaking naturally but clearly ‘as if talking to a child’, and looking directly into the camera;
- Be presented via a video / laptop computer, silently, with no repetition;
- Have a picture-pointing multiple-choice response.

Section B: Development of the first version of the Test of Adult Speechreading (TAS)

Initial test development followed these stages, which will be described in sections 4.8 to 4.10:

- Development of test items (including piloting, described in Appendix C)
- Test administration
- Preliminary reliability and validity investigations

4.8 Development of Test Items

“Whatever material one produces is open to criticism on almost innumerable counts” (Bench et al. 1979, pg. 108)

All test items were developed while endeavouring to maintain ‘natural’ language. No attempt was made to phonemically balance the test items, because of the small number of items it would be possible to include (in order to keep the test reasonably short), and because such ‘balancing’ would only be occurring at some rather abstract

level (Rosen & Corcoran 1982): coarticulation effects alter the visual as well as the acoustic representation of sounds.

4.8.i Single words

The speechreading subtest based on single words was developed from a pool of 157 nouns: 100 monosyllables and 57 two-syllable words, 39 of which were spondees (see Appendix B). All of the words were chosen to be easily and clearly represented as a picture, and to be in common use. Many of the words were selected from the BKB sentences (Bench et al. 1979), and from the Manchester Speechreading Test (Markides 1980). The BKB sentences were developed from language produced by 240 eight to fifteen year old children in schools for the deaf in the Berkshire area. The Manchester words were mainly selected from the book ‘Words your children use – an infant vocabulary source for Leicestershire Education Committee’ compiled by Edwards and Gibbon (1959). Both tests have been used with deaf adults (and the Manchester Speechreading Test, with deaf children) with no reported vocabulary difficulties. Thus, it was hoped that the words would be in the vocabulary of prelingually deaf adults.

Colour pictures for each word were selected from the ArtToday website (<http://www.arttoday.com>), edited for clarity, and resized so that each measured 36mm² when printed. Two profoundly prelingually deaf adults (one male, one female) then scrutinised the words and pictures. Where there was more than one possible picture for a word, the female judge (the first to examine the words) chose the one that she believed would be clearer to profoundly prelingually deaf adults (the target population). Any words or pictures that they did not believe to be suitable (that is, would not be readily recognised by the target population) were discarded. Fourteen words were discarded in this way.

A requirement of the items was that they should be of a high frequency for the target population. However, frequency data has not been collected for a prelingually deaf population, so it was decided to investigate the familiarity of the items as an alternative. During piloting, a list of the 144 single words was given to two profoundly prelingually deaf adult volunteers (one male and one female) working in a youth hostel for the deaf. They were asked to rate the familiarity of each word on a three-point scale:

1: very familiar 2: familiar 3: less familiar

The sum of these ratings gave each word a familiarity score between 2 (two ratings of ‘very familiar’) and 6 (two ratings of ‘less familiar’). The ten words with a rating of 6 were discarded (see Appendix B).

4.8.ii Sentences

42 sentences were developed in groups of three with a common theme so that the picture set would provide some contextual (topic) information. Topic information is usually available during everyday communication, and is likely to facilitate speechreading (see section 3.9). Care was taken to ensure that the sentences were syntactically simple, colloquial in style, and made up of appropriate vocabulary. The choice of sentences was limited by their potential for illustration: suitable pictures were selected from the ArtToday website. This method of illustration was chosen because it was the most cost- and time-effective. A target picture and two distracters were chosen for each sentence so that testees would need to understand more than one word to identify the correct picture. The pictures, like those for the single word subtest, were edited and resized so that each measured 36mm² when printed. Two profoundly prelingually deaf adults (one male and one female) then scrutinised the sentences and adjusted the language so that it was suitable for (that is, would be readily recognised by) the target population.

4.8.iii Stories

Each story was written using simple, colloquial language and vocabulary, and consisted of two or three sentences. The situations described were illustrated by a single picture (the target picture). Eight distracter pictures, which included items from the story, were also selected so that the target could not be identified on the basis of a key word or phrase. Again, items were limited by the availability of suitable pictures on the ArtToday website. In addition, a topic picture was selected for each story to provide contextual information, to cue participants in to the topic of the story.

4.8.iv Piloting: Three pilot investigations were undertaken in order to select the test items to be used, and to establish the test administration procedure. These pilot investigations are described in Appendix C. The resultant professionally recorded test video consisted of:

- Instructions in British Sign Language, signed by a native deaf signer. These instructions were a little slow, and required some modification when shown to

testees, because the instructions had been changed slightly since their recording (see Appendix C). The instructions were also printed on cards so that they could be used as guidelines to ensure consistency in the information given when instructions were spoken (e.g. to hearing testees), or could be read by or to testees as appropriate.

- Two talkers (one male, one female), who each said the days of the week to familiarise testees with their speaking patterns, and then presented alternate sets of items in each subtest. For each item the talker began looking down, and looked up prior to speaking to engage the attention of the testee.
- 24 single **words** (16 monosyllables and 8 spondees), with two demonstration and four practice items (see Table 4.1 for the items included).
- 15 declarative **sentences**, varying in length from three to six words (4 three-word, 2 four-word, 5 five-word, 4 six-word), with three practice items (see Table 4.1).
- 5 **stories**, two to three sentences in length, with one demonstration, and one practice item (see Table 4.1).

An accompanying colour A5 response booklet contained:

- Five sets of twelve pictures for the single word subtest responses (1 practice, and 4 test sets), each arranged in a 3 x 4 grid with six targets (4 monosyllabic, 2 spondaic) and six distracters (4 monosyllabic, 2 disyllabic), such that no two words in a group were obviously visually alike when spoken (that is, no pictures were included as deliberate distracters).
- Six sets of nine pictures for the sentence subtest responses (1 practice and 5 test), each arranged in a 3 x 3 grid with three targets and six distracters (2 specifically chosen for each target). Each set of pictures (and therefore the three target sentences for that set) had a theme so that a glance at the picture set would give some topic context for the sentence seen, because people usually have some knowledge about the topic of sentence utterances when they occur in everyday situations. The five themes were: the beach, the playground, school, the farm, and the park.
- The nine pictures for each story item (1 demonstration, 1 practice and 5 test items) were presented on a new page in a 3 x 3 grid (the target picture and eight distracters). A topic context picture was provided next to the picture grid, and

testees' attention was drawn to this prior to seeing the story spoken to give them a clue about the topic of the story.

Table 4.1: Items included in the initial, video-based, version of the Test of Adult Speechreading (TAS) (*dn*: demonstration items; *a-d*: practice items; 1-15: test items)

Words	dn	Eyebrow	dn	Spoon	a)	Tree	b)	Bus	c)	Football	d)	Fish
	1)	Thumb	2)	Sandwich	3)	Rings	4)	Cat	5)	Peacock	6)	Ear
	7)	Toothbrush	8)	Cup	9)	Ice-cream	10)	Pen	11)	Sun	12)	Dog
	13)	Door	14)	Lightbulb	15)	Wave	16)	Suitcase	17)	Knife	18)	Glass
	19)	Headlights	20)	Shoe	21)	Bed	22)	Key	23)	Snowman	24)	House
Sentences	a)	They're eating dinner.			b)	They're under the table.			c)	She drinks on her own.		
	1)	The girl plays with a ball.			2)	The man sunbathes.			3)	He drops his ice-cream.		
	4)	The children run.			5)	The boy plays on the slide.			6)	Her mum pushes the swing.		
	7)	The teacher writes on the blackboard.			8)	The boy holds a book.			9)	They look at the computer.		
	10)	The cow sleeps.			11)	The sheep stands.			12)	He feeds the pig.		
	13)	The man walks the dog.			14)	They sit on the bench.			15)	The boy plays with the dog.		
Stories	dn	Jim didn't like going to the doctor. He'd had an injection and it hurt his arm.										
	a)	Tigger the cat was clumsy. She chased a bird up a tree, but a branch snapped and she nearly fell.										
	1)	Bob went on holiday. He'd packed everything he needed, but he left his suitcase at home.										
	2)	Tom did the shopping every Friday. He got everything he wanted, but he could never remember where he'd parked the car.										
	3)	Paul's dad had just painted the kitchen chairs. Paul didn't notice and sat down on one. When he got up he was stuck to the chair.										
	4)	Bill took his dog camping. There was a hole in their tent and it rained all night. When they woke up, their tent was half full of water.										
5)	Mary wanted to surprise her dad because it was his birthday. She bought him a present and tied it with a red ribbon. Then she left it outside his door.											

4.9 Test Administration and Scoring

The test was administered individually to 109 testees (49 severely-profoundly prelingually deaf, 60 hearing). All testees had average or above average non-verbal IQ (tested on the block design test from the WAIS), normal or corrected to normal

vision, and reported no additional disabilities; their demographic information is summarized in Table 4.2.

Testees were seated approximately two meters from a television screen on which the images of the talkers' head and shoulders were approximately life-size. The test administrator was seated so that she could comfortably see the testee's responses, operate the remote control to pause the video as necessary, and answer any queries. The three subtests were presented to all testees in the same order (words, sentences, then stories), in one sitting, with no repetition. Testees were instructed to point to the picture that best matched each spoken item. A score of 1 point was given for each correct response, and 0 points otherwise, giving a maximum possible test score of 44.

Table 4.2: Demographics of testees who completed the pilot, video-based, version of the TAS

Hearing status	Parents	Total (N)	Female (N)	Age range (years)	Mean age (years)
Deaf	Hearing	38	23	21-61	39.95
	Deaf	11	5	18-48	31.91
Hearing	Hearing	49	24	18-68	31.55
	Deaf	11	8	21-51	32.36

4.10 Preliminary reliability and validity investigations

4.10.i Reliability (Internal Consistency)

The internal consistency of the TAS was calculated using Cronbach's alpha. Since the test items are not equally weighted and are marked as either right or wrong, this reliability index is identical to Kuder Richardson (KR) 20 (Alderson et al. 1995). The TAS was found to have high internal consistency ($\alpha = .904$).

4.10.ii Validity

Concurrent Validity: Ten hearing testees were tested on the first two sentence lists from the BKB as well as the TAS. They achieved much lower scores on the BKB sentences (see Table 4.3). However, the scores on the two tests were highly correlated ($r = .87$, $p < .002$), indicating that the two tests assessed essentially the same skill. This also contributes to the construct validity of the TAS since the BKB is assumed to assess speechreading.

Table 4.3: Summary of % scores on the TAS and the first two lists of BKB sentences

	TAS (%)	BKB (%)
Range	39 – 89	4 – 34
Mean	74.2	20.8
S.D.	15.38	10.42

Content and Response Validity: Three expert judges (an Audiologist, a Speech and Language Therapist, and a Researcher, who each worked professionally with deaf adults and were familiar with and skilled in administering a variety of assessments) completed questionnaires about the TAS with ratings on a 7-point scale. This information also contributed to the assessment of construct validity.

The means (indicated in red) and ranges (shown in blue) of their ratings are shown below. In each case, '1' is poor, and '7', good.

1. *General rating: How good a test of speechreading is the TAS?*

1 2 3 4 5 6 7

2. *Suitability for target population: How suitable is the TAS for profoundly prelingually deaf British adults?*

1 2 3 4 5 6 7

3. *Rating of part 1: single words*

1 2 3 4 5.3 6 7

4. *Rating of part 2: sentences*

1 2 3 4 5 5.6 6 7

5. *Rating of part 3: stories*

1 2 3 4 5 6 7

The mean ratings are all between five and six inclusive, indicating that the three judges rated the TAS very highly. In the opinion of these experts therefore, the TAS has high content and construct validity. The majority of their comments were positive. However, it was noted that, despite the distracters, it was possible to respond to the story items correctly through guessing on the basis of one word. Two experts felt that the test as a whole was too long, and one found the use of the video and test book a little unwieldy.

The testees were also asked to introspect on their performance on the TAS. All testees who commented reported that they felt it was their speechreading ability that had been tested.

These indications of the high reliability and validity of the Test of Adult Speechreading indicated that it was a potentially useful measure of speechreading ability, and therefore warranted further development.

4.11 Analysis of the results of the video-based version of the TAS

Scores obtained on the video-based version of the Test of Adult Speechreading (TAS) ranged from 16 (36%) to 44 (100%). The breakdown of scores by subtest for the deaf and hearing testees is shown in Table 4.4. It can be seen that the video version of the TAS produced a range of scores for each subtest, but that the mean scores were high. The histograms in Figure 4.1 illustrate the distribution of scores on the TAS, and show that ceiling effects are limiting the discriminatory power of the test, particularly for the deaf testees.

Table 4.4: Scores obtained on the video version of the TAS by deaf and hearing testees

	Subtest	No. of items	Min	Max	Mean	% mean	S.D.
Deaf	Words	24	11	24	20.90	87.08	3.15
	Sentences	15	4	15	11.08	73.87	3.17
	Stories	5	0	5	3.41	68.20	1.50
	Total	44	16	43	35.37	80.39	7.19
Hearing	Words	24	10	24	19.28	80.33	3.45
	Sentences	15	5	15	10.40	69.33	2.48
	Stories	5	0	5	3.93	78.60	1.34
	Total	44	17	44	33.6	76.36	6.56

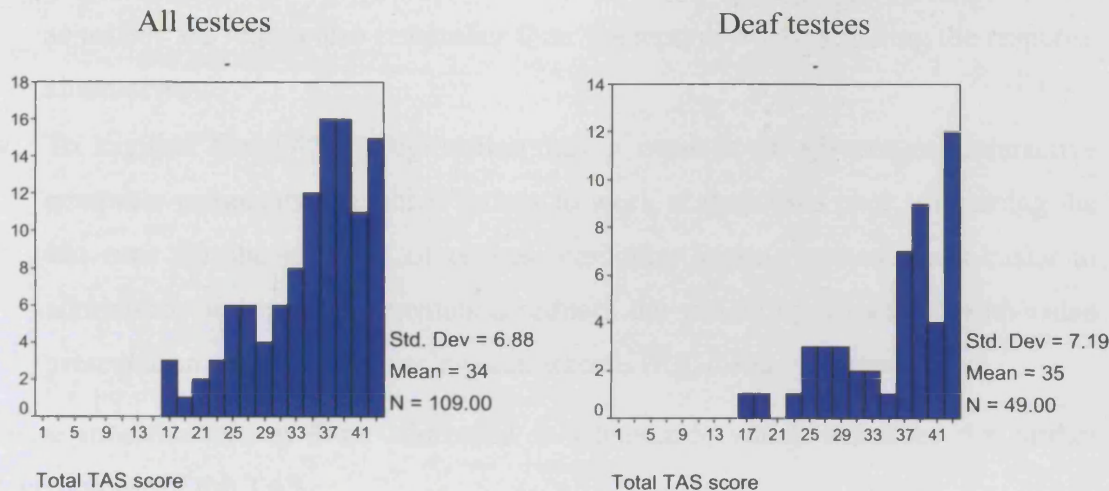


Figure 4.1: Histograms of performance on the video version of the TAS

In addition to ceiling effects, the following weaknesses were identified:

- The small number of items in the story subtest (5 items) meant that it contributed less than the other subtests to the overall test score.
- Item analyses showed that several items in the single word subtest were not discriminatory.
- Re-using picture sets for consecutive test items resulted in responses to one item influencing responses to other items in the same set.
- The variable number of distracters across subtests meant that the probability of a correct guess response varied.
- Two of the expert judges felt that the test was too long
- The video presentation together with the test-book was unwieldy.

4.12 Test modifications

The following decisions were made to remedy the weaknesses identified above:

- To include equal numbers of items in each subtest.
- To include a new picture set, with five distracters, for each test item in each subtest. The most common number of response alternatives in speech tests is four to six (Dillon & Ching 1995). A choice of six pictures gives a probability of a correct response based on guessing alone of .17, which is acceptably low. At the same time, the reduced number of pictures makes the picture scanning easier. Scanning a large number of pictures increases the load on working-term memory,

as testees are required to remember their perception whilst scanning the response alternatives.

- To digitise the TAS. Digitisation has a number of advantages: interactive computer presentation enables testees to work at their own pace, shortening the test time for the majority of testees; computer scoring makes a test easier to administer; and laptop presentation reduces the variability associated with video presentation using different television screens (e.g. different screen sizes).

These modifications will be addressed in Chapter 5, which describes the further development of the TAS.

Chapter 5

TEST DEVELOPMENT II:

FURTHER DEVELOPMENT AND ANALYSIS OF THE TEST OF ADULT SPEECHREADING (TAS)

5.1 Introduction

Chapter 4 described the initial development of the Test of Adult Speechreading (TAS), following a review of speechreading assessments which informed test development. In this chapter, the development and digitisation of the TAS following piloting with the video version will be described. The chapter is made up of two sections:

- A. Further test development, including modifications to the three subtests following item analysis of the video version of the test, piloting of the modified test, and filming and digitisation.
- B. Investigation of the test properties, including reliability, validity and item analysis.

Section A: Further Test Development

5.2 Modifications to the TAS subtests

5.2.i Word subtest

Scores were particularly high on the single word subtest. Item analysis showed that over 100 (92%) of the 109 participants responded correctly to six of the words items; these non-discriminatory items were therefore excluded from the next stage of test development. Three further items were excluded because additional factors influenced participants' performance on them: the spoken token of 'knife' in the video version of TAS was confused frequently with 'glass' (only 49% of participants selected the knife picture, and 39% selected glass). This affected participants' responses to 'glass', which was the next item (they were unwilling to respond with the same picture twice). Also, the picture for 'curtain' in the single word subtest was frequently identified as 'wind' and selected in response to "wave" (which is visually similar to "wind"). These contaminating factors meant that 'knife', 'glass' and 'wave' had not been piloted as effectively as the other items. The remaining fifteen items were included in the next stage of test development.

Distracters for each item were chosen based on participants' responses to the video-based TAS: the five most frequently selected distracters were included. Where a picture was selected as a distracter for more than one item, an alternative picture of that distracter was selected from the ArtToday website. The pictures were presented in a 2 x 3 grid, ensuring that pictures for repeated distracters did not appear in the same grid positions, and that the position of the target picture varied randomly.

5.2.ii Sentence subtest

All fifteen of the items in this subtest were retained, with only minor changes. For each item, the two deliberately chosen distracters were retained, with the three most frequently chosen additional distracters. The deliberately chosen distracters had been included originally to ensure that more than word of each sentence would need to be understood for a correct response to be made, and the majority had proved effective distracters. Again, where a picture was selected as a distracter for more than one item, an alternative picture of that distracter was selected from the ArtToday website. The pictures were presented in a 2 x 3 grid, ensuring that pictures for repeated distracters did not appear in the same grid positions, and that the position of the target picture varied randomly.

5.2.iii Story subtest

This was the subtest given the lowest rating by the professionals asked to act as expert judges in the investigation of content validity (see section 4.10.ii). Even though the distracters had been chosen to prevent it, one of them commented that it was possible to respond to these items correctly through guessing on the basis of just one word. This was possible because one word could in some cases reduce the picture choice to two or three pictures, increasing the probability of a correct guess accordingly. It meant that the subtest was not necessarily assessing connected speech comprehension. Given, in addition, the small number of story items, and the difficulty associated with capturing a story in one picture with scope for sufficient distracter pictures, there were compelling arguments for a complete change in the subtest's design.

Ten new short (2 to 4 sentence) stories were written. As before, they were simple, colloquial, and made up of frequent, familiar words. In addition, three questions, which could be answered through a picture-pointing response, were written about each story (see Table 5.2, pg. 138).

The items were written so that the correct responses could not be guessed from the questions asked, or from general life knowledge. Distracters that could all be reasonable answers to the questions were chosen for each.

Five stories (each with three questions, making a total of 15 subtest items), plus the practice story, were selected in consultation with colleagues experienced in research with deaf people. These stories were then checked by a profoundly prelingually deaf colleague to ensure that the language would be accessible to deaf adults, and minor changes were made accordingly. The items were ordered from shortest to longest, since difficulty was expected to increase with utterance length.

5.3 Pilot investigation of the modified TAS

Participants: Ten adults (four male; age range 22 – 51 years, mean age 29 years) with normal hearing, normal or corrected-to-normal vision, and no reported disabilities took part in this pilot investigation.

Test Materials: The test materials, spoken by the female talker from the first version of the TAS, were recorded on a mounted digital camcorder in a well-lit room against a plain background. This recording was edited using Adobe Premiere to include captioned item numbers and blank response times. The response pictures for each item were colour printed on A5 paper. The items included are detailed in Table 5.2.

Methods: The participants were instructed to point to the picture that matched the item spoken for the word and sentence subtests, and to answer the questions in the story subtest by pointing to a picture. They were invited to comment on the test and on any improvements they thought could be made.

Results: The descriptive statistics for these participants' scores on this pilot version of the modified TAS are shown in Table 5.1.

Table 5.1: Descriptive statistics from pilot of the modified TAS

	Min	Max	Mean	% Mean	S.D.
Word subtest	9	15	12.5	83.3	2.12
Sentence subtest	2	11	8.8	58.7	2.94
Story subtest	1	9	4.4	29.3	2.41
Total test score	17	35	25.7	57.1	5.76

No participant achieved a total test score of more than 77.8% (35 / 45) in this pilot. The ceiling effect for the test as a whole appears, therefore, to have been removed.

Table 5.1: The test items included in the pilot investigation of the modified TAS

Words		Sentences		Stories	
(a)	<i>Fish</i>	(a)	<i>They're under the table.</i>	<i>Ben was going to the circus. On the way he stopped at a shop and bought a banana.</i>	(a) <i>Where was Ben going?</i>
(b)	<i>Watch</i>	(b)	<i>She drinks on her own.</i>		(b) <i>Where did he stop?</i>
(c)	<i>Tree</i>	(c)	<i>They're eating dinner.</i>		(c) <i>What did he buy?</i>
(d)	<i>Eyebrow</i>				
1	rings	1	The girl plays with a ball.	Last year I went on holiday with my son. We stayed in a tent and went fishing every day.	1 Who did I go with?
2	shoe	2	The children run.		2 Where did we sleep?
3	headlights	3	The teacher writes on the blackboard.		3 What did we do?
4	door	4	The cow sleeps.	The little girl's favourite game is tennis. She also likes watching television, but she hates reading.	4 What is her favourite game?
5	key	5	The man walks the dog.		5 What else does she like?
6	cup	6	The man sunbathes.		6 What does she hate?
7	ice-cream	7	The boy plays on the slide.	My friend is in hospital. Last week he was skiing down a hill when he hit a tree and hurt his head.	7 What was my friend doing?
8	cat	8	The boy holds a book.		8 What did he hit?
9	dog	9	The sheep stands.		9 What did he hurt?
10	sandwich	10	They sit on the bench.	The farmer drove into town on his tractor. He bought some carrots and took them home to feed his cow.	10 How did he get to town?
11	pen	11	He drops his ice-cream.		11 What did he buy?
12	suitcase	12	Her mum pushes the swing.		12 Who were they for?
13	toothbrush	13	They look at the computer.	Helen got up early, but forgot to put her glasses on. She went down stairs and saw a long shape in front of the fire. She called her husband to ask him what it was. He said it was only an umbrella.	13 What did Helen forget?
14	bed	14	He feeds the pig.		14 What did her husband say she saw?
15	sun	15	The boy plays with the dog.		15 Where did she see the shape?

Word subtest

The scores on the word subtest have remained high (with a risk of ceiling effects), despite the removal of the easiest items. However, this pilot was carried out with only one talker, and may thus have been easier than the final assessment (with two talkers) would be, since increasing the number of talkers in a speechreading assessment can decrease the resultant scores (see Yakel et al. 2000). In addition, the participants' comments indicated that the ease of this subtest contributed to their enjoyment of the test and increased their motivation. Further item selection was not, therefore, considered necessary. Minor picture alterations, which were suggested by the participants, were made for clarity. The items were also reordered so that pictures representing the same word did not appear for consecutive items (one participant had noticed the repetition), and, as far as possible, they appeared in order of difficulty (with the easiest items first).

Sentence subtest

The sentence subtest discriminated well between participants. No participant scored above 73.3% (11 out of 15), so there was no evidence of a ceiling effect. Item analysis, considered with the participants' comments, revealed that one of the distracters needed changing. A distracter for the sentence 'The boy holds a book.' was a picture of a boy holding a globe. This had been confusing because the globe had been mistaken for a ball; which is visually similar to "book". This distracter was changed for a picture of a boy holding a frog. Other than this, only minor picture alterations were made for clarity. The items in this subtest were also reordered. The practice items were arranged in order of difficulty, and the triplets of sentence items, which had previously formed sets, were split up so that the similar pictures were separated as much as possible. The first items of each set formed items 1 to 5, the second of each set became 6 to 10, and the third, 11 to 15.

Story subtest:

The new design of the story subtest was found to be appropriate: it was the most difficult subtest (with a maximum score of 60%), but discriminated well between participants. Item analysis showed an unusually high score for one item (90% of the participants answered the question 'What did he hit?' for the third story correctly). This may have been because the correct answer was the most logical, so the story was changed so that an alternate response was correct ('tree' was changed to 'rock'). In

contrast, no participant responded correctly to the first question about the first story ('Who did I go with?'). The correct answer had been 'son', but comments from the participants suggested that the target picture was not clear. The story was therefore changed so that an alternate response was correct ('son' was changed to 'dog'). Other than this, only minor alterations were made to the pictures for clarity. The order of this subtest was not changed: the stories remained ordered by length.

5.4 Filming and Digitisation

The male talker from the first, video-based version of TAS was no longer available for filming, so a new male talker from southern England, with English as his first language, clear speech, and no obvious accent, was selected. This talker was judged to be more difficult to speechread than the original talkers. This was considered to be advantageous as it could potentially limit any ceiling effects in the word subtest.

Both talkers (the new male talker, and the female talker from the video-based TAS) were filmed individually saying all of the test items with voice. For each item, they were instructed to begin looking down, and then to look up, directly at the camera, and speak the item naturally at the rate that they would use if they were telling a story to a child. The instruction to look up prior to speaking was given to obtain the speechreader's attention and cue them that the next item was about to be spoken. The rate instruction was given to encourage a natural, but slightly slower than normal speech rate because this has been found to be the preferred speechreading rate for deaf testees (e.g. Berger 1972b, see section 4.4.vi). Each item was repeated two or three times to ensure that a suitable token was captured.

The test stimuli were filmed audiovisually, with a head and shoulders view, using a canon XL1 DV camcorder and a Brüel & Kjær sound level meter (type 2231) with attached microphone (type 4165). The talkers wore plain, non-distracting clothes, with no distracting jewellery. The male talker was clean shaven since, although varying degrees of facial hair have not been found to have significant effects on speechreading performance, some hearing impaired participants have indicated that it is distracting (Kitano et al. 1985). The female talker wore no make-up, since lipstick has also been reported as a distracting element (DiCarlo & Kataja 1951), and her hair was tied back so that it would not be distracting and did not obscure any part of her face.

Signed instructions for the test, questions for the story subtest, and the practice items (translated for feedback) were also filmed. A deaf native signer translated the instructions and questions from written English into BSL, and was filmed signing them in a full body view against a blank background. Care was taken to ensure that translation into BSL did not provide clues about the correct responses to the questions. The feedback for the practice items were not translated into BSL, but signed to give the information in the same order that it had been spoken (that is, in SSE).

The stimuli and instructions were transferred into Adobe Premiere, and the resultant AVI files edited using the same program. The best example of each item for each talker was selected: files were discarded if the utterance were accompanied by a shift of eye gaze, or by a distracting change in facial expression, or included any talker error. The clearest examples were then selected for inclusion, and edited so that the file began just before the talker looked up, and ended just after s/he looked down after saying the item. They were then cropped so that each talker's head and shoulders were equally sized in a 720 x 576 frame. The remaining AVI files were retained in case piloting revealed any item-specific problems.

The selected stimulus and instruction AVI files were converted into MPEGs using the TMPGEnc programme¹⁶ because the comparatively small size of this file type facilitated smooth (skip- and judder-free) digital playback of the items. The assessment program was written in Visual Basic by Dr Mike Coleman. This new digital test version followed the same basic format as the video version. The program, once running, is operated by the testee using a mouse.

It comprises:

- A choice of language for the test instructions (BSL or written English)
- An introduction (in the chosen language) explaining the test format
- Each talker saying the days of the week (to allow testees to begin to familiarise themselves with their speaking patterns)
- Instructions for each subtest (followed by the option to repeat the instructions once if required)

¹⁶ <http://www.fmpgenc.net>

- Presentation of practice items (the option to repeat the practice items once for each subtest is given at the end of the practice set):
 - *Word & Sentence subtests:*
 1. A 'ready' button at the bottom of the screen (this ensures that testees are attending to the screen at the beginning of each item, and that the mouse is not obscuring any part of the talker's face during the stimulus presentation)
 2. The video clip of the spoken stimulus (sized 20 x 15cm on the laptop screen)
 3. The response picture grid (testees click on a picture to respond, the pictures are highlighted as the mouse moves over them)
 4. Feedback: a tick if correct, or a cross if incorrect with the correct picture in the grid highlighted, and the item written or signed
 - *Story subtest:*
 1. & 2. as above
 3. Three questions, asked in the respondent's chosen language (BSL or written English), each followed by a response picture grid
 4. a) Feedback after each response: a tick if correct, or a cross if incorrect, with the correct picture in the grid highlighted
 b) Feedback after all three questions: the story written or signed (depending on the testee's language choice)
- Presentation of test items: as for the practice items, with the omission of feedback.

The test items and screen shots from the TAS programme are presented in Appendix D. The program can be used to present the test material in audiovisual or visual only conditions since the stimulus files have sound. To present the test silently for the research reported in this thesis, the sound was muted on the laptop used. The program also records the testee's responses and reaction times into a named file. This file can be explored from within the program as soon as the test has been completed. The administrator therefore has immediate access to a testee's scores.

5.5 Summary

The Test of Adult Speechreading (TAS) is an assessment of the ability to visually perceive and identify spoken English words, sentences and short stories. It requires testees to view a short speech segment and then to match it to one of an immediately following set of six pictures. Test instructions and practice feedback are delivered in

the preferred communication mode of the respondent (written English or British Sign Language), and the vocabulary and syntax used in the speech segments was selected as being as appropriate for use with d/Deaf people. The test items are spoken by two native British English talkers, one male and one female, seen speaking each item alternately, in a head and shoulders full-face view. The talkers were recorded audiovisually under frontal illumination as they spoke the test items using natural speech patterns. The digitised video clips are displayed on a laptop computer. Experimental software is used to display each clip, followed by its corresponding picture response set, and to record each participant's responses.

Section B: Investigation of the test properties

This section will investigate the properties of the Test of Adult Speechreading (TAS), and addresses the following questions:

- Is the TAS a valid and reliable assessment of speechreading in deaf and hearing adults?
- Are the administration procedures satisfactory?
- Are the test items discriminatory?
- Does performance on the test items reflect known predictors of item difficulty?
- Does performance differ as a function of talker?

The analyses reported here are for 135 adults (50 deaf) who have completed the TAS core subtests. This includes participants who were excluded from later analyses because they did not fit the selection criteria for the work described in later chapters (due to for example, prelingual, but not congenital, deafness), however, all included testees had a non-verbal IQ score higher than two standard deviations below the mean. Later-excluded participants are not excluded from the majority of the analyses here because this chapter focuses on the properties of the test, rather than on the performance of the participants as a function of other variables.

5.6 Reliability

5.6.i Internal consistency reliability

The internal consistency of the TAS was calculated using Cronbach's alpha, a model based on the average inter-item correlation. Since the data is dichotomous, this reliability index is identical to Kuder-Richardson 20 (KR20) coefficient (Alderson et

al. 1995). The TAS was found to have acceptably high internal consistency¹⁷ ($\alpha = .801$).

Inter-talker reliability is an additional measure of split-half / internal consistency. The correlation between performance on the items spoken by the male and female talkers respectively is highly significant ($r=.643, p<.001$).

5.6.ii Test-retest reliability

Twenty-nine participants (22 deaf, 7 hearing) were retested on the TAS core subtests after a lag of between two and seven months. As Figure 5.1 illustrates, the test-retest relationship was highly significant ($r=.858, p<.001$). This correlation exceeds the minimum of $r=0.8$ recommended for test-retest investigations (Kline 1993), and therefore constitutes further evidence of the acceptably high reliability of the Test of Adult Speechreading (TAS).

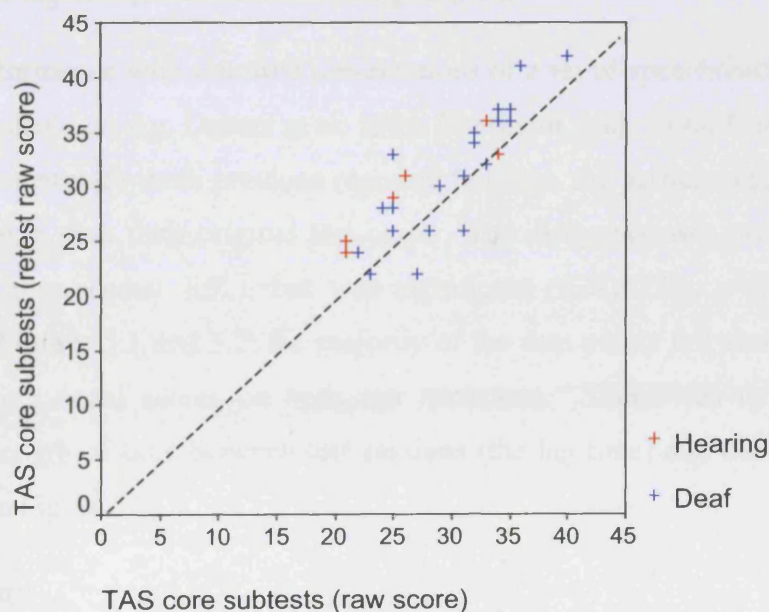


Figure 5.1: Scatterplot illustrating the relationship between test and retest scores on the TAS core subtests

¹⁷ Cronbach's alpha should be $> .7$ (Clark-Carter 2002; Kline 1993)

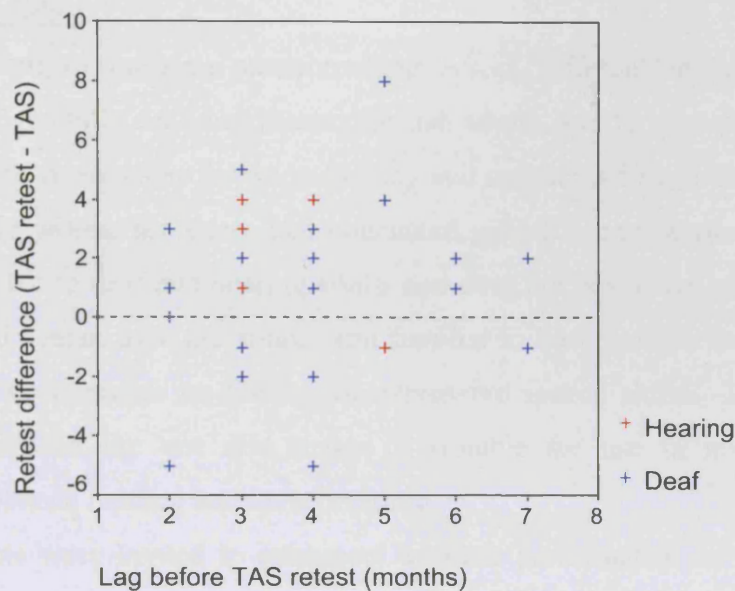


Figure 5.2: The difference in the testee's test and retest scores on the TAS as a function of the lag in months between testing sessions

Increased performance with repeated presentations of a set of speechreading materials is well established (see e.g. Dancer et al. 1994; Eberhardt et al. 1990; Plant & MacRae 1981). Consistent with these previous reported findings, the participants' mean retest score was higher than their original test score. The difference was not great (mean difference in raw scores: 1.52), but was significant ($t(28)=2.86, p<.01$). This is illustrated in Figures 5.1 and 5.2: the majority of the data points fall above the dotted lines illustrating equal scores on both test occasions. There was no relationship between the length of time between test sessions (the lag time) and the difference in the scores (see Figure 5.2).

5.7 Validity

"It is best to validate a test in as many ways as possible"

(Alderson et al. 1995, pg. 171)

Concurrent, content and response validity investigations were carried out during pilot investigations of the TAS (see section 4.10). These provide evidence of the test's high validity. Further investigations of the face and construct validity of the TAS are described below.

5.7.i Face Validity

The test set out to measure speechreading across different linguistic levels in profoundly congenitally deaf and hearing British adults, and to be suitable for use in investigating the relationship between literacy and speechreading ability. Test items comprise single words, sentences and connected speech (short stories). The test is equally accessible to deaf and hearing adults and does not advantage either group: the vocabulary and syntax used are simple and familiar to both groups, and the response format makes no demands on literacy or expressive speech skills. The absence of literacy demands in the test also makes it suitable for use in investigating the relationship between reading and speechreading.

The participants were invited to introspect on their performance on the TAS. All participants who commented reported that they felt it was their speechreading ability that had been tested. The face validity of the test is therefore upheld.

5.7.ii Construct Validity

One measure of the construct validity of a test is the correlation between the different test components (Table 5.3). The subtests are expected to correlate moderately with each other, since they are intended to measure slightly different aspects of speechreading. The correlations between the subtests and the whole test would, according to classical test theory, be expected to be higher (Alderson et al. 1995) because the overall score should be a more general measure of ability than each individual subtest score. The subtests were correlated with the test total minus the subtest in question because the correlations between the subtests and the total are artificially inflated by the inclusion of each subtest in the total.

Table 5.3: Inter-subtest correlation matrix for all testees (N = 135)

		Sentences	Stories	Total	Total minus self
Words	<i>r</i>	.608	.273	.768	.547
	<i>p</i>	.000	.001	.000	.000
Sentences	<i>r</i>	--	.351	.858	.581
	<i>p</i>	--	.000	.000	.000
Stories	<i>r</i>	--	--	.707	.354
	<i>p</i>	--	--	.000	.000

As expected, the subtests correlated moderately, but significantly, with each other, and the correlations between the subtests and the total was higher: the subtests each

test a slightly different speechreading skill, and the total score gives a more general measure of speechreading ability. The story subtest has the lowest correlations with the other measures, indicating that the difference in the skills required for this subtest may be greater.

5.8 Test administration

Participants were able to complete the test without any difficulties in following the test procedure. Feedback from the participants who chose to receive the instructions in written English and BSL respectively indicated that the written and signed instructions are clear and appropriate. Feedback also indicated that the number of items, testing time and language level in all subtests is satisfactory.

5.9 Item analysis and factors affecting test difficulty

5.9.i Single Words

Item analysis: The percentage of participants who responded correctly to each single word item is illustrated in Figure 5.3. It can be seen that, while there were no items to which 100% of the participants responded correctly, over 90% of participants were correct on 9 items (2, 3, 5, 6, 7, 9, 11, 13 & 14).

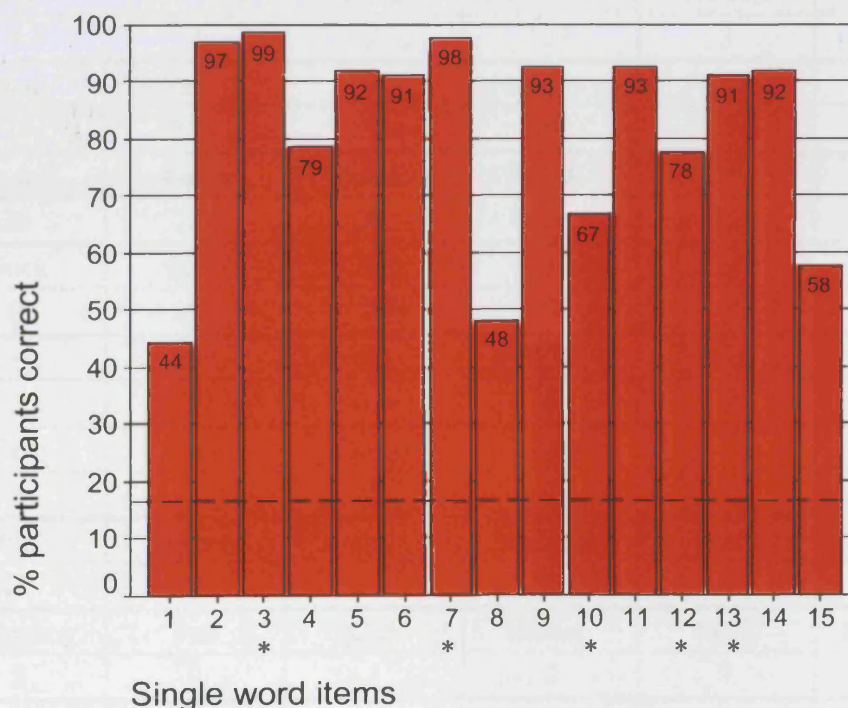


Figure 5.3: Percentage of correct responses to the single words subtest items (dashed line indicates chance level, * indicates spondaic items)

Effectiveness of distracters: Each participant's error patterns were analysed by picture position. There were no unusual or inappropriate error patterns (e.g. repeated selection of a single picture position). Table 5.4 shows the frequencies of the responses to each of the response choices. It can be seen that (apart from items where there were very few errors) errors were distributed fairly evenly across the distracters.

Table 5.4: Frequencies of responses to the single word subtest items (N=135; A to F represent grid positions of response choices; **red** indicates correct response)

	A	B	C	D	E	F
1	Dog	Cow	Sun	Ball	Hedgehog	Snail
	60	10	10	40	11	4
2	House	Shoe	Snowman	Slide	Chair	Whistle
	1	131	1	0	2	0
3	Sandwich	Peacock	Tent	Ear	Swing	Table
	133	1	0	0	0	1
4	Present	Heart	Hedgehog	Cup	Ice-cream	Ball
	5	5	5	106	8	6
5	Horse	Knife	Brush	Wave	Door	Lightbulb
	7	0	0	3	124	1
6	Slide	Balloons	Duck	Headlights	Whistle	Pig
	4	2	2	123	3	1
7	Sun	Toothbrush	Dog	Hedgehog	Present	Cup
	0	132	1	0	0	2
8	Swing	Table	Snake	Bird	Tent	Rings
	26	2	21	6	15	65
9	Duck	Key	Chair	Whistle	Slide	Snowman
	0	125	10	0	0	0
10	Cup	Ball	Pen	Snail	Sun	Present
	1	30	90	6	0	8
11	Cake	Door	Orange	Glass	Suitcase	Wave
	4	1	0	2	125	3
12	Pig	Whistle	Bed	Balloons	Duck	House
	11	2	105	5	5	7
13	Hedgehog	Pen	Cup	Heart	Snail	Ice-cream
	2	0	1	2	7	123
14	Bird	Tent	Cat	Peacock	Snake	Ear
	1	5	124	1	2	2
15	Snail	Dog	Present	Cow	Toothbrush	Sun
	41	8	2	6	0	78

Number of syllables: The single words subtest is made up of 10 monosyllables and 5 spondee (the spondee is indicated by stars in Figure 5.3, pg. 147). Spondee words were expected to be easier in line with previous findings (e.g. Erber 1971; see section 4.3.v). As expected, a greater percentage of participants responded correctly to the spondee words than to the monosyllables (see Figure 5.4). This difference did not, however, reach significance ($U=19.5$, $p=.513$, NS).

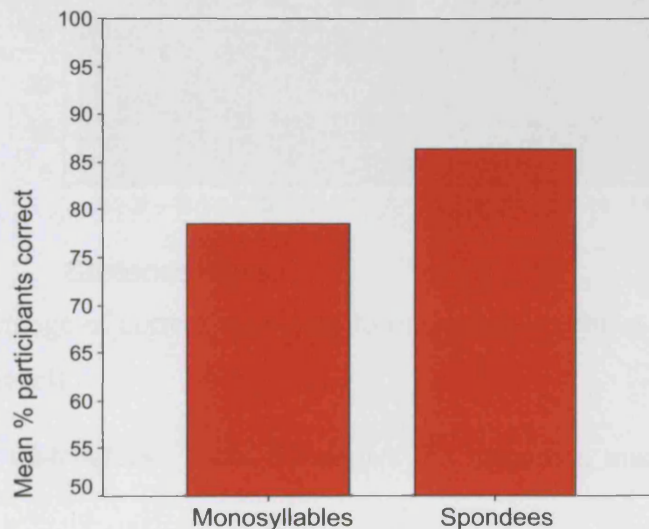


Figure 5.4: Bar chart illustrating the percentage of testees who responded correctly to the monosyllabic and spondaic single word TAS items

5.9.ii Sentences

Item analysis: The percentage of participants who responded correctly to each sentence item is illustrated in Figure 5.5. It can be seen that between 33% and 91% of participants responded correctly to each item. There are no floor or ceiling effects evident for this subtest.

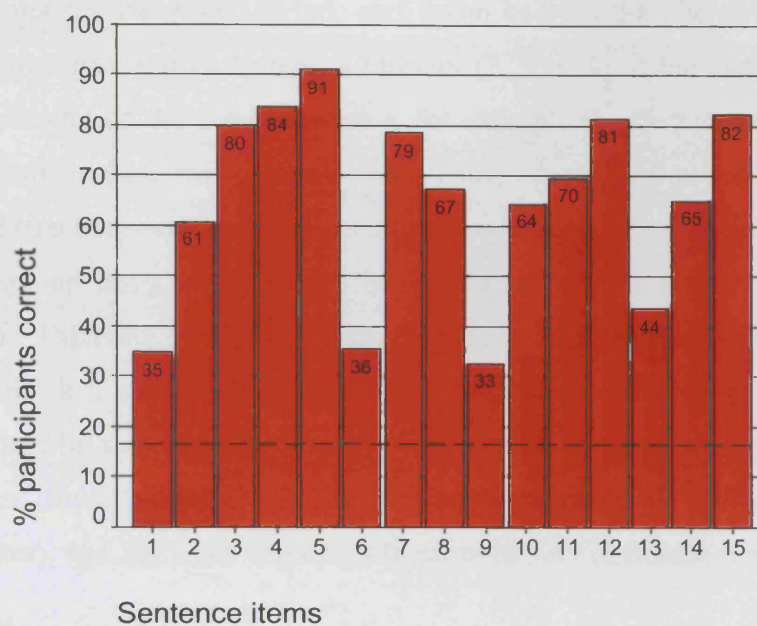


Figure 5.5: Percentage of correct responses to the sentence subtest items (dashed line indicates chance level)

Effectiveness of distracters: Table 5.5 shows the responses made to the sentence subtest items.

Table 5.5: Frequencies of responses to the sentence subtest items (N=135; ; A to F represent grid positions of response choices; **red** indicates target responses, **blue** indicates linked distracters)

		A	B	C	D	E	F
1	The girl plays with a ball.	47	1	23	12	52	0
2	Her mum pushes the swing.	3	13	14	82	17	6
3	The teacher writes on the blackboard.	1	3	108	2	19	2
4	The cow sleeps.	8	5	0	2	7	113
5	The man walks the dog.	2	4	2	123	4	0
6	He drops his ice-cream.	22	10	7	29	19	48
7	The boy plays on the swing.	4	9	0	106	2	14
8	They look at the computer.	14	6	9	8	91	7
9	The sheep stands.	0	44	4	65	16	6
10	They sit on the bench.	10	87	6	8	7	17
11	The man sunbathes.	94	0	5	2	5	29
12	The children run.	11	2	2	5	110	5
13	The boy holds a book.	36	4	13	0	23	59
14	He feeds the pig.	3	1	88	4	36	3
15	The boy plays with the dog.	111	15	3	1	2	3

The target responses are shown in red, and it can be seen that the errors are spread across the distracters. For each item, a number (2, 3 or 4) of the distracter pictures depicted an element of the target sentence, for example the distracters for 'The girl plays with a ball' include two pictures which feature a girl, and two which include a ball. These distracters were included in initial test development to prevent the correct response becoming obvious following the identification of a single key word (see section 4.8.ii). There are 40 of these distracters across the sentence subtest, indicated in Table 5.5 in blue, and 35 distracters that did not depict anything from the target sentence. It can be seen that the majority of incorrect responses were linked to the target sentence: there were 522 'linked' responses (a mean of 13.05 responses per linked distracter), and 192 other responses (a mean of 5.49 responses per distracter).

5.9.iii Stories

Item analysis: The percentage of participants who responded correctly to each story item is illustrated in Figure 5.6. It can be seen that performance on 6 of the items (3, 8, 9, 13, 14 & 15) was close to (or in the case of item 14, below) chance level. Binomial tests confirm that the proportion of participants responding correctly to these items does not differ significantly from the chance level of .167.

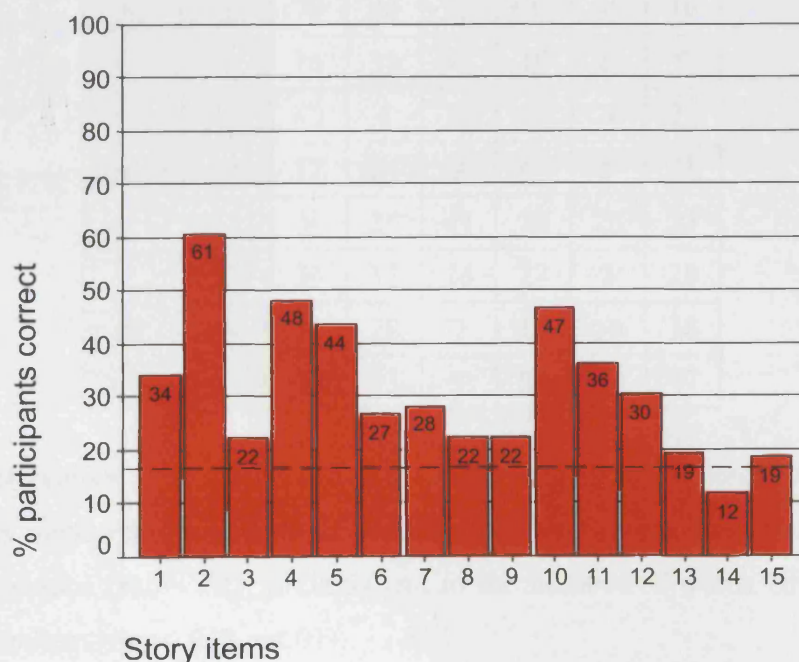


Figure 5.6: Percentage of correct responses to the story subtest items (dashed line indicates chance level)

Effectiveness of distracters: As for the other subtests, each participant's error patterns were analysed by picture position. It can be seen from Table 5.6 that the errors were distributed across all of the distracters, indicating that they were, as intended, all feasible answers to the questions. It is notable that a high proportion (52%) of participants continued to select distracter A (tree) in answer to the story C's second question, 'What did he hit?'. This was the item that was changed following piloting (see section 5.3).

Table 5.6: Frequencies of responses to the story subtest items (N=135; A to F represent grid positions of response choices; **red** indicates correct response)

Story	Item	A	B	C	D	E	F
A	1	9	3	37	19	21	46
	2	3	23	82	2	15	10
	3	24	36	9	27	30	9
B	4	6	65	20	19	17	8
	5	5	24	21	59	7	19
	6	8	40	10	7	34	36
C	7	39	6	9	19	24	38
	8	70	30	13	5	7	10
	9	16	30	41	10	29	9
D	10	63	4	14	9	24	21
	11	17	24	9	49	5	31
	12	8	20	41	20	23	23
E	13	34	17	26	27	3	28
	14	30	28	7	16	16	38
	15	12	13	5	33	25	47

Length of utterance: The stories varied in length from 16 to 42 words. As expected, difficulty (as measured by number of participants correct) was negatively related to length of utterance ($\rho = -.723, p < .005$) and to the number of words before the key word for each item ($\rho = -.668, p < .01$).

5.9.iv The Talkers

Participants responded correctly to significantly more of the items spoken by the female talker than to those spoken by the male talker (see Figure 5.7; $z=-4.19$, $p<.001$ ¹⁸).

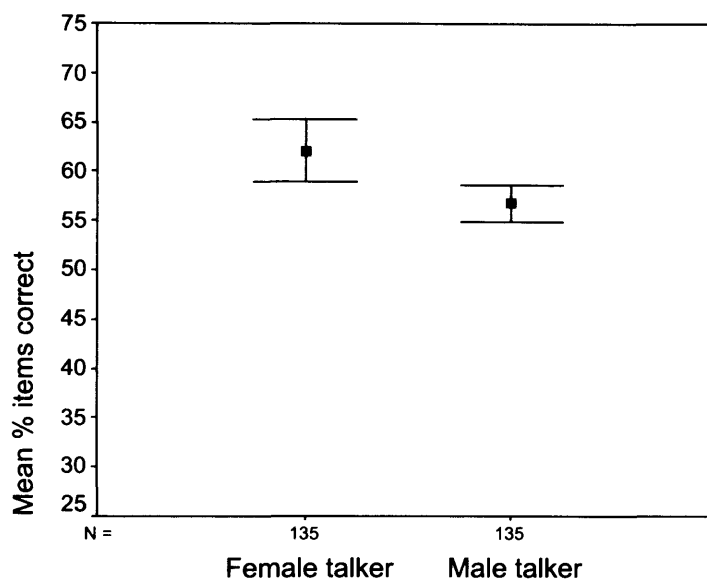


Figure 5.7: The mean percentage performance on items spoken by the female and male talker respectively (error bars show a 95% confidence interval)

5.10 Summary

Is the TAS a valid and reliable assessment of speechreading in deaf and hearing adults?

Yes. The TAS has been found to have acceptably high reliability and validity.

Are the administration procedures satisfactory?

Yes. All administration procedures proved satisfactory.

Are the test items discriminatory?

The majority of test items are discriminatory. However, there are ceiling effects for some items in the single words subtest, and floor effects for some items in the stories subtest that could usefully be addressed in future test development. Overall, the test is discriminatory, and avoids ceiling and floor effects. The comparatively easy single word subtest promotes participant enjoyment and helps to maintain motivation, and the comparatively difficult stories subtest provides a challenge for the best speechreaders.

¹⁸ A Wilcoxon signed-rank test was used to analyse these data because performance on the female items was not normally distributed (Shapiro-Wilk statistic = .971, $df=92$, $p<.05$)

Does performance on the test items reflect known predictors of item difficulty?

Yes. As expected, performance on the spondaic single word items was slightly higher than performance on the monosyllables. In addition, speechreading performance on the story subtest decreased as utterance length (in number of words) increased. This was expected following previous findings (e.g. Boothroyd 1988; Green et al. 1981b; see section 4.3.v).

Does performance differ as a function of talker?

Yes. The female talker appears to be easier to speechread than the male talker. No generalisations can be drawn from performance with a single talker of each gender, but this difference is in line with previous findings that females are easier to speechread than males (Daly et al. 1996; see section 4.4.ii).

The Test of Adult Speechreading (TAS) is, then, a valid, reliable, discriminative and sensitive speechreading assessment tool, suitable for use with d/Deaf and hearing British adults. The remaining chapters of this thesis describe its use in investigating speechreading in profoundly congenitally deaf adults.

Chapter 6

THE SPEECHREADER:

DEMOGRAPHIC VARIABLES THAT AFFECT SPEECHREADING PERFORMANCE

6.1 Introduction

In this thesis, the Test of Adult Speechreading (TAS, described in detail in Chapter 5) was used to investigate speechreading in a group of congenitally profoundly deaf British adults, and, for comparison, a group of hearing British adults. In this chapter, the speechreading performance of these groups will be considered with respect to their hearing status, and also other demographic variables, including their parental hearing status, gender, age, intelligence, and personality, and deaf-specific variables such as hearing aid use and language experience and preference.

This chapter consists of 3 sections: Section A reviews previous findings from the literature; Section B describes the methods; and Section C describes the results and discussion.

Section A: Literature Review

6.2 Comparison of Deaf and Hearing Speechreaders

There is considerable disagreement in the literature over the respective speechreading abilities of hearing and deaf people. Some of the variation in the findings can be accounted for by considering the participants and methodologies selected: ‘deaf’ and ‘hearing’ people do not form homogenous groups (see Chapter 2), they could each be further divided into subgroups (for example, by degree of hearing loss, or language preference for the deaf group) and the subgroups would still not be homogenous. Some authors have been very selective in the individuals they chose to compare, or have assessed the two groups differently, and this makes it difficult to draw general conclusions about the relative speechreading skills of deaf and hearing people. For example, in some of the studies the deaf participants were stringently selected to have speechreading as a socially important and well-practised skill. Since the participants were so carefully selected, it is not clear how far the results would generalise to other

deaf adults. Sign language users, for example, often do not consider speechreading important to the majority of their communication. Examples of studies comparing the relative speechreading skills of deaf and hearing individuals, with the methodological and participant selection factors that may have affected the results are considered in Table 6.1.

Table 6.1: Examples of methodological and participant selection effects on group comparisons

Author (date)	Better performance by deaf / hearing?	Result may have been affected by...
Pelson & Prather (1974)	Deaf older (51-59 yrs) adults outperformed hearing older (52- 61 yrs) adults.	Deaf group had acquired hearing losses (duration ranged from 7 to 25 yrs). They are therefore likely to have had English language skills equivalent to those of the hearing group. These results may not generalise to prelingually / congenitally deaf people.
Clouser (1976a; 1977)	No significant difference (hearing slightly better)	Hearing participants were university students, deaf participants were reading at sixth-grade level. This is likely to have given an advantage to the hearing group since the required test responses were written.
Conrad (1977; 1979)	No significant difference (deaf children slightly better)	The hearing group received the whole test as a practice but the deaf group did not. This may have enhanced the hearing group's performance.
Risberg & Agelfors (1978)	Deaf	The seven severely deaf participants chosen were all orally trained and had good speech and language skills
Green et al. (1981a)	Hearing children better on words, phrases & sentences (closed- set picture responses)	Young children (5-6yrs): the deaf children may not have developed the English language knowledge required.
De Filippo (1984)	Hearing adults on consonants (small differences) Deaf adults on words (again, small differences)	The deaf group were all orally trained, the hearing group had some training in phonetics
Elphick (1996)	Deaf adolescents	The deaf participants were prelingually deaf, wore a hearing aid, and had sufficient memory and language skills to repeat a 6-word sentence.
Bernstein et al. (2000) Demorest & Bernstein (1997)	Deaf adults	The deaf participants and their families used English as their native language (excluding American Sign Language users), they had all been educated in a mainstream and/or oral setting, and were all severely or profoundly deaf undergraduate students.

No consensus has been reached on the relative speechreading skills of deaf and hearing people. On one hand, authors have reported finding that hearing children speechread better than deaf children (e.g. Dodd 1980; Green et al. 1981a; Lowell et al. 1959). This lead Mogford (1987) to claim: “That auditory experience of speech enhances visual speech recognition is shown by the fact that the hearing are more competent at lip-reading than the deaf” (pg. 191).

The mixed findings have lead others to conclude that there is no overall difference between deaf and hearing abilities, just large individual differences in speechreading skill. Summerfield (1991), for example, states, “it is to be lamented that excellence in lipreading is not related to the need to perform well, because in formal laboratory tests..., the best totally deaf and hearing-impaired subjects often perform only as well as the best subjects with normal hearing” (pg. 123). Rönnberg (1995) reviewed the literature concerning this question and also concluded that there was no evidence for enhanced performance in relation to auditory experience. There have been a number of studies in which no significant difference was found between the two groups (Clouser 1976b; Clouser 1976a; Clouser 1977; Conrad 1977; Conrad 1979; Lyxell & Rönnberg 1989), supporting Nitchie’s belief that there is “no inherent reason why a hearing person cannot learn to read the lips as well as one who is deaf” (1915, pg. 435).

There is, however, an argument that deaf people “should develop a greater ability in speechreading than their hearing peers because they are more dependent on it” (Elphick 1996, pg. 357). It is typically claimed that approximately a third of speech can be understood through speechreading, but one profoundly deaf speechreader is quoted as saying

“Would you continue using a form of communication that allowed you to understand only one third of what people said to you? ... I have many friends, deaf from birth or infancy, ... who do all their communicating through speech and speechreading. We have had hours of conversations using speech and speechreading alone, and I know they understood much more than one-third of what I said!” (Gonzales 1982, quoted by De Filippo 1990, pg. 48).

A number of researchers have found that deaf individuals *can* attain a higher mean speechreading score than normal hearing participants (e.g. Bernstein et al. 2000; Demorest & Bernstein 1997; Elphick 1996; Markides 1980; Pelson & Prather 1974;

Risberg & Agelfors 1978; Utley 1946). This does not imply that deafness is a sufficient condition for even moderately accurate speechreading. Even where a deaf group has, on average, been found to outperform a hearing group, some of the deaf participants were as inaccurate as the hearing individuals. However, Bernstein and colleagues (2000) suggest that the conditions associated with auditory deprivation may be favourable to enhanced visual phonetic perception.

If we accept that there are systematic differences in the speechreading abilities of deaf and hearing people, despite the heterogeneity of the groups, we then have to ask why. Sections 6.2.i and 6.2.ii detail the (generalised) advantages that each group has over the other in developing speechreading skills.

6.2.i Advantages for hearing people in a speechreading task

- 1) *Auditory-visual experience*: From infancy, hearing people are sensitive to the audio-visual patterns of speech (see section 2.16). Auditory information facilitates infants' visual attention, and they direct their gaze towards a speaking face. Within their first year they begin to develop a phonemically based awareness of visual speech (e.g. Aldridge et al. 1999; Burnham & Dodd 1998; 2004; Dodd 1979; Kuhl & Meltzoff 1982; 1984; 1988; Patterson & Werker 2003; Walton & Bower 1993c; Walton & Bower 1993b; Walton & Bower 1993a).
- 2) *English language knowledge*: Hearing people may be expected to speechread better than their deaf peers because "their relatively superior knowledge of the language should facilitate its visual recognition" (Green et al. 1981a, pg. 505). Hearing speechreaders are likely to have larger spoken vocabularies and better English language skills than their deaf counterparts (see Chapter 2, Section E). Good linguistic skills enable the speechreader to draw on phonotactic, syntactic, semantic and pragmatic cues in decoding a visually presented spoken message.
- 3) *Articulation*: A number of previous studies have suggested a relationship between articulation skills and speechreading ability (e.g. Conklin & Subtelny 1980; Desjardins et al. 1997; Siva et al. 1995; Siva 1995; but see Dodd et al. 1983). This is in line with the motor theory of speech perception (Liberman & Mattingly 1985, see sections 2.10 and 3.5): people with better articulation skills are likely to have richer knowledge about the motoric and kinaesthetic correlates of speech gestures, which are hypothesised to be the objects of perception. Most hearing adults do not have any difficulty with articulation, however it has been reported

that only about 25% of deaf children develop intelligible speech (Beattie 2006; Cole & Paterson 1984).

- 4) *Literacy*: Many existing speechreading assessments require written responses. This may give an advantage to hearing speechreaders since deaf people typically have lower levels of literacy than their hearing peers (see e.g. Conrad 1979; Dyer et al. 2003). They may therefore be less able or willing to write their responses. In addition, reading and speechreading have been found to correlate in deaf adults (e.g. Bernstein et al. 1998a) and children (Harris & Moreno 2006; Kyle & Harris 2006). The relationship between these two means of visually perceived language comprehension is likely to be complex and reciprocal (see section 2.24, and Chapter 9), but strong literacy skills may be expected to give hearing people an advantage in speechreading, whatever the response required.
- 5) *Phonological coding and processing* are fundamental to audiovisual speech processing and assumed to hold a central role in speechreading (see e.g. Rönnerberg et al. 1998; and section 3.7). However, profound congenital deafness is likely to result in less efficient phonological coding skills (see section 3.8), and lexical-phonological representations that are less well specified than, and differ from, those of hearing people.
- 6) *World and social knowledge*: There is a strong possibility of deficits in these knowledge areas in prelingually deaf people (Boothroyd 1988) due to the isolation that deafness can cause (see sections 2.15 and 2.23). This is likely to adversely affect speechreading ability since it limits top-down processing ability (see section 3.9).

6.2.ii Advantages for deaf people in a speechreading task

- 1) *Overt awareness of speechreading*: Conrad wrote that “Lip reading is something which happens to the hearing; deaf people do it” (1979; pg. 202). The latter may depend on speechreading in much of their everyday communication (at least when communicating with hearing people). This dependence leads to increased awareness: deaf people have been found to be able to more accurately judge their own speechreading performance on a subjective confidence rating scale than hearing people (Demorest & Bernstein 1997). The overt awareness that deaf people have of their speechreading abilities may enable them to capitalise on their strengths and compensate for their weaknesses in speechreading, as well as

leading to the conscious practice of speechreading as a skill (see point 3, on ‘training and practice’ below). It may therefore facilitate enhanced speechreading skills. This will be investigated in sections 6.15.

- 2) *Motivation* governs the initiation, direction, intensity, and persistence of behaviour (Evans 1989), that is, it determines how attention is directed and focussed. Motivation may therefore impact on speechreading accuracy by determining how and how well the speechreader utilises their perceptual and cognitive abilities (see Chapter 4, pg. 113-114). This is hypothesised to be important because speechreading is cognitively demanding and requires sustained attention. Accordingly, speechreading accuracy has been found to be related to motivation levels (Berger 1972a; Lidestam 2002). A sub-group of deaf people – those who choose to communicate principally through speech – are extremely motivated to speechread proficiently.
- 3) *Training and practice*: Many deaf people receive explicit speechreading training at school and/or at lipreading classes later in life. Hearing people do not receive this training. A deaf person’s lifelong reliance on speechreading in their everyday communication with hearing people also leads to their awareness of speechreading as a skill (see point 1, above) that they may consciously practice. Hearing people, on the other hand, are not normally aware of speechreading at all. Researchers have long postulated that speechreading skill should improve with training and practice, and speechreading does show a strong practice effect (see e.g. Dancer et al. 1994). Individuals’ scores on speechreading assessments have also been found to increase following training. For example, training with nonsense syllables has been found to result in improvements in phoneme identification for both deaf (Walden et al. 1977; Walden et al. 1981) and hearing (Gesi et al. 1992; Massaro et al. 1993) participants. In general, short-term training/practice has been found to result in small but significant improvements in speechreading similar materials (e.g. Bernstein et al. 2001; Black et al. 1963; Heider & Heider 1940; Hutton 1960; Lowell et al. 1959). The effect that training has on functional, everyday speechreading ability is less clear.
- 4) *Phonological-lexical representations based on visually perceived speech* rather than dominated by acoustic information: Hearing people perceive visual and auditory information together, and integrate it from a very early age (e.g. Burnham & Dodd 2004, see section 2.16). For them, visual information is always

perceived with, and dominated by, the auditory speech signal, and their phonological-lexical representations are assumed to reflect this auditory dominance. The representations of congenitally deaf people, on the other hand, are likely to reflect their experience of perceiving speech, and to be dominated by visual (speechread) information. Some deaf adults are able to perceive a higher proportion of the phonemes in speechread sentences than their hearing peers (Bernstein et al. 2000) and are more sensitive to the distinctions between words which are visually highly confusable, such as 'bat', 'pat', and 'mat' (Bernstein et al. 1997; see section 3.3). This may enable deaf speechreaders to extract the phonological / linguistically useful information from visually perceived speech more efficiently, and to make better use of talker-specific information (that is, to be better at 'normalizing' it, see section 3.6).

- 5) *Enhanced visual perception:* Arnold & Köpsel (1996) suggest that hearing children may be limited in speechreading by their perceptual skills, implying that the skills of deaf children are superior. Deaf people do show an enhanced peripheral response to visual information (Bavelier et al. 2000; Bavelier et al. 2001; Neville & Lawson 1987a; Neville & Lawson 1987b; Neville & Lawson 1987c), and peripheral space and motion information is processed differently in the deaf brain (Neville & Bavelier 1998; Tomann et al. 1998). In addition, native signers have been shown to exhibit enhanced facial processing (Bettger et al. 1997). These factors may enhance the performance of deaf speechreaders through a greater ability to pick up and use additional cues, such as facial expression and gesture, seen in the periphery of their vision, and through an enhanced response to motion, since speechreading involves decoding rapidly moving seen oral signals. This will be investigated in Chapter 8.

The goal of speechreading is the same for all individuals, regardless of their hearing status: it is to understand spoken English (or any other language) through vision. However, it does not necessarily follow that all people use the same combination of skills or strategies. It is likely that there is more than one way of speechreading, that some processes, skills or strategies may be more important or effective than others, and that there are systematic differences in the strategies used by different groups, such as hearing and deaf adults, which are dependent on their relative strengths and weaknesses. For example, deaf people may, as a group, use their perceptual skills

more in speechreading, or make greater use of cues such as facial expression and situation, while hearing people may use their knowledge of English to guess at the words they cannot decode.

6.3 Demographic Variables

6.3.i Gender

The majority of the research in this area indicates that on average, deaf and hearing females speechread sentences better than males (Blager & Alpiner 1981; Dancer et al. 1994; Markides 1980; Plant & MacRae 1981), although this difference has not always been found to reach significance (e.g. Demorest & Bernstein 1992). Dancer and colleagues (1994) found evidence of female speechreading superiority in all age groups tested (20-29, 30-39, 40-49, 50-59, 60-69). Female speechreaders have also been found to improve their speechreading ability at a faster rate than males (Daly et al. 1996; Dancer et al. 1994). Dancer and colleagues (1994) suggests that these findings may be in line with those of female superiority in language and reading skills (Moir & Jessel 1991; Springer & Deutsch 1981).

6.3.ii Age

Plant, Phillips and Tsembis (1982) found no discernible trend of visual alone scores as a function of increasing age in deaf adults, although there was a gradual decline in scores for the auditory and auditory-visual conditions. However, the majority of studies have found a trend for hearing adults: Farrimond (1959) found that, with his test materials, speechreading performance peaked at 30 years of age, and declined at 8% per decade from then on. Dancer and colleagues' (1994) data agree with these findings of peak performance in the thirties, and then a decrease as a function of increasing age. Using the CID Everyday Sentences, Cienkowski and Carney (2002) found that younger adults (aged 18 to 35 yrs) speechread better than older adults (aged 65 to 74 yrs). Similarly Shoop & Binnie (1979) and Walden, Busacco and Montgomery (1993) found that the speechreading performance of older people fell below that of middle-aged adults.

A number of factors may account for these findings, including caution and reduced visual proficiency. Farrimond (1989), Honnell and colleagues (1991), and Walden and colleagues (1993) noted that older adults were more cautious, and reluctant to guess, than younger adults. Honnell and colleagues (1991) found a significant correlation between percent correct and number of written words for their older

participants, and some commented that they were reluctant to write anything down in case it was wrong. Caution, or willingness to guess may therefore be one important factor in the reduction of speechreading skill in older people (see section 6.3.iv for further discussion of willingness to guess and speechreading). It is possible, however, that there would still be a decrease in speechreading performance with increasing age if this were eliminated (as it is in the Test of Adult Speechreading), because as the eye ages, presbyopic changes affect proficiency on a number of visual tasks (Thorn & Thorn 1989). Older viewers extract less information from a complex visual configuration and demonstrate diminished ability to detect human faces (see e.g. Owsley et al. 1981).

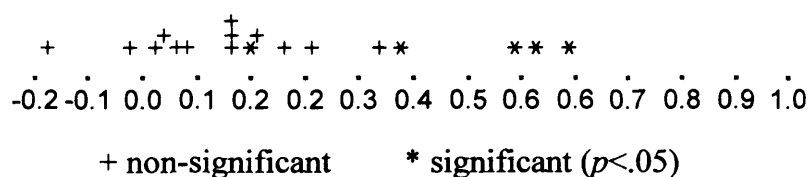
There are additional factors for the deaf participants that may impact on their speechreading ability differently for different age groups. Younger adults may make more, and more effective, use of hearing aids due to improvements in aid technology (see section 2.7). Sixty years ago, aids were expensive, bulky, of poor quality and therefore useless to severely and profoundly deaf people. These are the aids that would have been available to the oldest participants in their early school years. The younger participants, on the other hand, have throughout their lives had access to aids that are discrete, resilient, and powerful enough to be useful to some profoundly deaf individuals. In addition, there have been many changes in education for deaf people (see Chapter 2, Section C). These changes may impact on the deaf participants' speechreading: the younger participants may be relatively advantaged.

6.3.iii Education level and Intelligence

A smaller proportion of deaf than hearing people achieve higher education qualifications: in 2003, deaf people were reported to make up just 0.27% of the 1,294,100 tertiary student population (RNID 2003b). At around the time the oldest deaf participants included in this research were leaving school the real focus of their education was on basic skills and speech. Preparation for their after-school life was changing away from vocational training in a handful of trades, as industrialisation had made a number of those trades obsolete. Sainsbury (1986) found that only 6% of the deaf people she interviewed had left school with a CSE, matriculation school certificate or an O or A level. Although deaf adolescents now follow the National Curriculum, as do their hearing peers, poor literacy skills (Conrad 1979; Dyer et al. 2003; Harris & Beech 1998; Paul 2001; see section 2.24) mean that few achieve good

school leaving qualifications and can go on to further or higher education. Factors such as this, and communication difficulties in a hearing-speaking workplace, may account for the high numbers of deaf people who are unemployed. A survey carried out in 1999 (RNID 2003a) found that respondents had an unemployment rate of 19%, four times the national average. Deaf people with better English language skills are likely to have higher educational achievements than those with poorer skills because good results in standard examinations in the UK require good English skills, and they are a requisite for higher education. Higher levels of education are therefore expected to be associated with better speechreading scores for the deaf participant group.

For the hearing participants, all of whom spoke English as a native language, higher levels of education are expected to be associated with intelligence¹⁹. It seems logical that intelligence should influence speechreading (Markides 1989a), especially since visual processing of the speech signal is more cognitively demanding than audiovisual speech perception (Rönnberg et al. 1998). However, where a significant positive correlation has been found between speechreading and IQ, (Conrad 1977; Craig 1964; Montgomery 1966; Montgomery 1968; Neyhus & Myklebust 1969) it is small, and the majority of researchers report a low, positive, but *non-significant* correlation (e.g. Berger 1972b; Montgomery & Demorest 1988; Pintner 1929). This pattern of correlations (from these studies and others reported in a review by Jeffers & Barley 1971) is illustrated in Figure 6.1:



6.3.iv Risk-taking and Impulsiveness

“Speechreading is for the imaginative”

(Nitchie 1930, pg. xi)

People who are more willing to guess are classified as more extraverted than those who are more cautious. Extraverts have been found to look at a conversation partner’s face more than introverts (Mobbs 1968a; Mobbs 1968b), and this may impact positively on their speechreading experience and skill. In addition, caution, or willingness to guess, has been identified as a potentially important factor in the reduction of speechreading skill in older people (e.g. Honnell et al. 1991; see section 6.3.ii). Van Tasell & Hawkins (1981) found that encouraging guessing, even in young adults resulted in improved speech perception scores. Falconer & Mefferd (1970), studying adults with an acquired hearing loss, also found that good speechreaders made more guesses than poor speechreaders.

Willingness to guess is a personality factor, characterised by risk-taking and impulsiveness. This has not previously been directly investigated as a possible predictor of speechreading ability (although there was early interest in the impact of personality, see e.g. Wong & Taaffe²⁰ 1958). Deaf children and adults have been found to be more impulsive than their hearing contemporaries (e.g. Chess & Fernandez 1981; Lowenbraun & Thompson 1986; Meadow 1976; Parasnis et al. 2003).

Willingness to guess may be expected to impact on speechreading. The visually perceived speech signal is incomplete, poorly specified, rapid and transient. Even extremely good speechreaders therefore have ‘holes’ in the speechread messages they perceive. In everyday communicative speechreading, people who are more willing to guess (i.e. more impulsive & risk taking, less controlled & cautious) may be expected to be more likely to attempt to engage in communication where they will have to guess at the intended communicative message when they have understood only part of it. Their guesses can enable the communication to continue (where avoidance of guessing would abort it), and they may therefore experience more positive speechreading practice.

A measure of impulsiveness and risk-taking is expected to correlate with speechreading ability. This relationship is expected to be stronger for the deaf

²⁰ Their work was with young hearing adults; they found no consistent results with regards to personality and speechreading

participants because hearing individuals are unlikely to have consciously used speechreading in their daily lives and would not therefore have benefited from being willing to guess.

6.4 Experimental Questions and Hypotheses

6.4.i Do the speechreading abilities of deaf and hearing adults differ?

The results of previous research into this question have been contradictory, and often clouded by poor testing and under-specified or over-specific participant selection (see section 6.2). Taken as a whole, they suggest that there may be no overall difference between the groups, but that the best speechreaders may be deaf (see e.g. Bernstein et al. 2000).

6.4.ii Are there subgroups of deaf or hearing participants with superior speechreading abilities?

Parental hearing status: Within the hearing group, the HoD participants are expected to outperform their HoH peers (see Chapter 2, section F). Within the deaf group, however, the DoH and DoD participants each have relative speechreading advantages (see Chapter 2, Section D): those with hearing parents will have grown up surrounded by spoken language in the home, and may have had a stronger motivation to communicate through speech. The DoD participants, on the other hand, are likely to have been diagnosed earlier, to have benefited from better communication strategies in their early childhood, and to have developed better visual attention skills. Any difference between the speechreading performances of the two subgroups may, then, shed light on the relative importance of these factors in speechreading.

Deaf-specific variables:

Use of hearing aids: Deaf participants who use hearing aids are expected to achieve higher speechreading scores than those who do not (see section 2.7).

Language Preference: Deaf participants who choose to use English in their daily lives are expected to outperform those who do not (see Chapter 2, Section B).

Language used when growing up: Deaf participants who grew up with spoken English as the predominant language at home are expected to continue using speech throughout their lives and to outperform those who did not (see section 2.26).

School type: Deaf participants who were educated orally at school are expected to outperform those educated through Total Communication (see Chapter 2, Section C).

Age at first exposure to BSL: Speechreading performance is expected to be positively correlated with age at first exposure to BSL, that is, the later an individual was exposed to BSL, the better their speechreading performance is predicted to be (see section 2.9).

Other demographic variables:

Gender: Female speechreaders are expected to outperform males (see section 6.3.i).

Age: Speechreading performance is expected to fall with increasing age over approximately 30 years (see section 6.3.ii).

Non-verbal IQ: A positive, but non-significant, relationship is expected between speechreading performance and non-verbal IQ (see section 6.3.iii).

Level of Education: Speechreaders with higher levels of education are expected to outperform those with lower levels within the deaf group, reflecting the good English skills required for higher levels of education. The performance of these subgroups is not expected to differ for the hearing participants, since for them higher levels of education are expected to be associated with intelligence (see section 6.3.iii).

Risk-taking and Impulsiveness: Deaf participants who are more risk-taking and impulsive are expected to achieve higher speechreading scores (see section 6.3.iv). This measure is expected to correlate most strongly with the connected speech level of the TAS. No relationship is expected for the hearing group.

6.4.iii Are deaf adults better than hearing adults at rating their speechreading ability?

The deaf participants are expected to be able to rate their speechreading ability more accurately than the hearing group (see section 6.2.ii).

6.4.iv Do the patterns of speechreading performance on the TAS core subtests differ as a function of hearing status?

The deaf and hearing groups are expected to show different patterns of relative performance on the TAS, reflecting different speechreading skills and/or strategies.

Section B: Methods

6.5 Participants

Forty-one deaf and fifty-one hearing adults participated in the main studies reported in this thesis. No participant reported any additional disability impacting on their cognitive or language development, and all had normal or corrected to normal vision.

Participants with a non-verbal IQ score of lower than two standard deviations below the mean were excluded.

6.5.i Deaf participants

The deaf participants all had a hearing loss of over 90dB in the better ear, and reported an onset of their hearing loss at or before birth. Twenty-three had hearing parents (DoH), and eighteen, deaf parents (DoD). Potential participants were not selected on the basis of any language- or education-based criteria. Table 6.2 shows the demographic characteristics of these participants.

Table 6.2: Demographic characteristics of the deaf participants

		DoH	DoD	All Deaf
Age	Mean (yrs;mths)	37;2	31;11	34;11
	Range (yrs;mths)	24;1 - 60;1	21;5 - 56;11	21;5 - 60;1
Gender	Male (N)	7	8	15
	Female (N)	16	10	26
Age at diagnosis	Mean (months)	17.27	6.54	12.29
	Range (months)	6 - 48	0 - 24	0 - 48
Preferred language	BSL (N)	16	13	29
	Speech (N)	2	1	3
	Mixture (N)	5	4	9
Hearing aids?	Yes (N)	11	7	18
	No (N)	12	11	23

A number of potentially exclusionary factors were considered during participant selection, and investigated prior to the analyses presented below. These investigations are described in Appendix L. No participants were excluded on the basis of age at diagnosis, cause of deafness, refusal of audiometry, tinnitus, or regional spoken accent: these factors were found not to impact significantly on speechreading performance. It should be noted, however, that six participants' age at diagnosis was over six months or unknown, and their deafness due to a viral or unknown cause (see Appendix L: these participants' speechreading scores are illustrated in Figure L.3, pg. 431). There was no evidence to cast doubt on the deaf participants' reports that they were born deaf, but their results need to be interpreted with caution. Since the best speechreaders' age at diagnosis was post six months or

unknown, there is the possibility that some may not have been profoundly deaf from birth.

6.5.ii Hearing participants

Forty-one of the hearing participants had hearing parents (HoH), and ten had deaf parents (HoD). Table 6.3 shows demographic characteristics of these participants.

Table 6.3: Demographic characteristics of the hearing participants

		HoH	HoD	All Hearing
Age	Mean (yrs;mths)	34;7	32;8	34;2
	Range (yrs;mths)	16;0 - 76;1	22;9 - 56;4	16;0 - 76;1
Gender	Male (N)	16	2	18
	Female (N)	25	8	33

6.6 Materials

6.6.i Background Questionnaire

Participants each completed a questionnaire detailing demographic information, education and language history, and, for the deaf participants, information about their hearing loss. Copies of the questionnaires administered to the deaf and hearing participants respectively are in Appendices E and F.

6.6.ii Audiometry

The hearing levels of deaf participants who did not have a copy of a recent audiogram were tested using pure tone audiometry using a TA155 audiometer following the guidelines of the British Society of Audiology (see British Society of Audiology 1981 for detailed descriptions). The left and right ears were tested individually, starting with the reported better ear: each tone was played through headphones for one to three seconds with varied gaps of one to three seconds, starting with 1000 Hz, then 2000, 4000, 8000, 500, and 250 Hz. The testee indicated when they could hear a tone, for the entire duration of the tone, by pressing a button. For each frequency, a familiarization tone judged to be clearly audible to the testee (about 30 dB above their estimated threshold, or at the audiometer's maximum output 100 dB) was presented, and then the intensity level was reduced to identify the testee's threshold level for that frequency. The threshold of hearing is the level at which the tone was heard for 50% of the number of times it was presented at that level (at least two presentations out of

a possible three or four). The threshold decibel (dB) level at which the person was able to hear the tone for each frequency was plotted on a pure tone audiogram. Since each person's pattern of frequency sensitivity was different, the degree of deafness across frequencies was determined for each ear by calculating the mean hearing threshold levels at 250, 500, 1000, 2000, 4000 Hz. Where the threshold was above 100 dB, and therefore above the level it was possible to test with the available audiometer, the threshold was recorded as >100 dB. Fifteen of the deaf participants did not have recent audiograms but opted out of having their hearing tested. All self-reported a profound hearing loss.

6.6.iii Speechreading

The Test of Adult Speechreading (TAS, described fully in Chapter 5) was used to assess participants' speechreading skills. The test comprised single word, sentence and short story level subtests. These tasks yielded an accuracy score for each subtest, and a composite accuracy score.

In addition, after the participants had completed the speechreading tasks, they were asked to self-rate their speechreading ability on a scale of 1 (very poor) to 10 (very good).

6.6.iv Non-verbal IQ

The block design task from the Weschler Adult Intelligence Scale – revised (WAIS-R, Wechsler 1981) was used to estimate participants' non-verbal IQ. Instructions were given as recommended in the test manual in each participant's preferred language.

6.6.v Risk-taking & Impulsiveness

A measure of two of the participants' personality traits, risk-taking and impulsiveness, was obtained through the administration of the two relevant sections of a personality test ('Know your own mind'²¹) based on the Eysenck Personality Questionnaire (EPQ, Eysenck & Eysenck 1975). The EPQ has been described as "the best validated and most reliable instrument in personality psychometrics" (Flint, 2003²²). The two 31-question sections were combined into a single questionnaire (62 questions). Participants were required to answer each question by circling 'yes', 'no' or 'maybe', and were instructed to go through the questions fairly quickly without thinking too

²¹ <http://www.trans4mind.com/personality/>

²² <http://www.well.ox.ac.uk/flint/>

deeply about each one. The questions were translated into BSL as required for the deaf participants. For each question, either ‘yes’ or ‘no’ scored one point, and the other scored zero; ‘maybe’ always scored ½ point. The sum of these scores gave a risk-taking score on a scale from 0 (careful) to 31 (risk-taking), and an impulsiveness score on a similar scale: 0 (controlled) to 31 (impulsive). Figure 6.2 represents possible scores on each of the sections of the questionnaire, with the hearing population norm on each (as given by the test author) indicated in red.

Impulsiveness															Control															
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31

Risk-taking															Carefulness															
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31

Figure 6.2: Risk-taking and impulsiveness scales (the hearing population norms are indicated in red)

The two scores were combined to give a single score for each participant with possible range of 0 to 62. High scores indicated a relatively more impulsive, risk-taking person, and low scores, a relatively more controlled, cautious person.

Section C: Results and Discussion

The results for this chapter are arranged in the following sections:

- Do the speechreading abilities of deaf and hearing adults differ?
- Are there subgroups of deaf or hearing participants with superior speechreading abilities?
 - Parental hearing status
 - Deaf-specific demographic variables
(Use of hearing aids, language preference, childhood home language, type of school, age at first exposure to BSL)
 - Other demographic variables
(Gender, age, level of education, risk-taking & impulsiveness)
- Are deaf adults better than hearing adults at rating their speechreading ability?
- Do the patterns of speechreading performance on the TAS core subtests differ as a function of hearing status?

The distribution of the data for each scale variable was analysed and transformed as necessary prior to these investigations (see Appendix M.)

6.7 Do the speechreading abilities of deaf and hearing adults differ?

No overall difference was predicted between the speechreading performances of the deaf and hearing groups on the basis of previous research, but the best speechreaders were expected to be deaf (see section 6.2, and the brief summary in section 6.4.i).

The deaf participants achieved a mean score of 30.44 (S.D.= 5.05), and the hearing participants, a mean score of 25.16 (S.D.= 4.73) on the TAS. These data are illustrated in Figure 6.3.

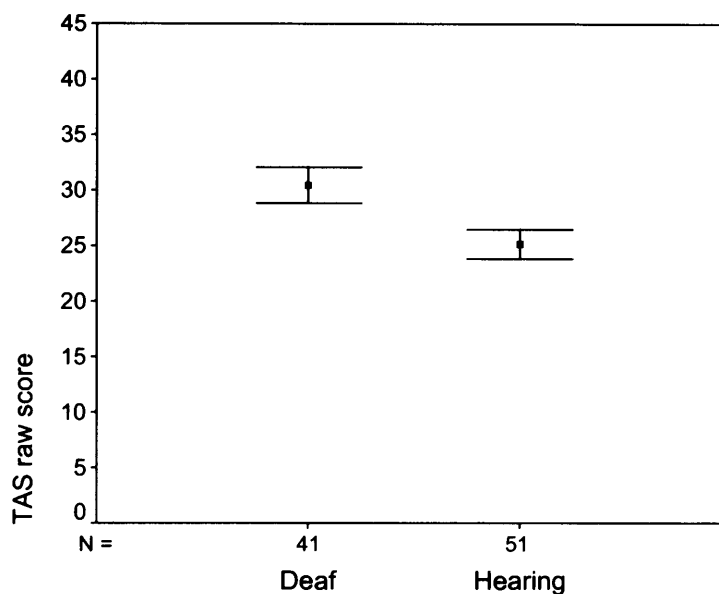


Figure 6.3: Mean raw scores on the TAS for the deaf and hearing participants (error bars show a 95% confidence interval)

The deaf group significantly outperformed the hearing group on the TAS core subtests ($t(90)=5.17$, 2-tailed $p<.001$). This difference was significant at every level of the TAS (words: $U=454.0$, 2-tailed $p<.001$, sentences: $U=642.5$, 2-tailed $p<.002$, connected speech: $U=720.5$, 2-tailed $p<.02$).

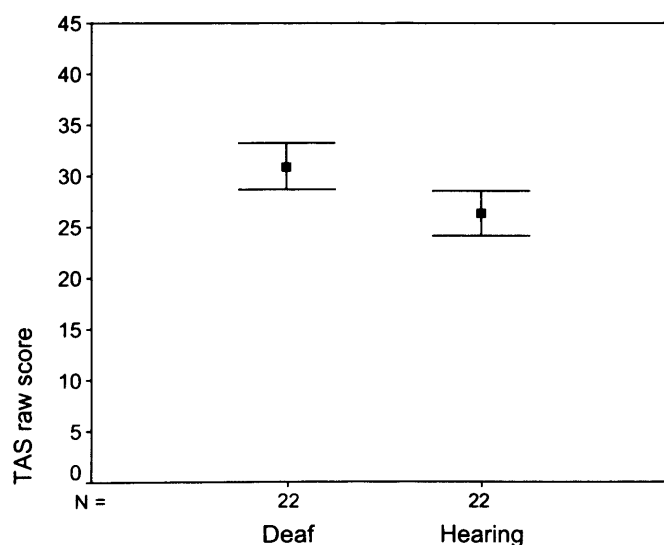
The deaf group still outperformed the hearing on the TAS when the six participants whose age at diagnosis was over six months or unknown, and whose deafness was due to a virus or an unknown cause were excluded ($t(84)=4.53$, 2-tailed $p<.001$), and even when only the twelve deaf participants who were diagnosed as deaf before they were six months old (see Appendix L) were included ($t(61)=2.37$, 2-tailed $p<.05$).

The difference between the deaf and hearing groups' performance was further verified by reducing the variability between the groups as far as possible: 22 pairs of deaf and

hearing participants were matched on

- *Age*: The pairs were matched to within 5 years; deaf mean age: 33;8, hearing mean age: 32;10
- *Gender*: 7 pairs were male, 15 female
- *Parental hearing status*: 7 pairs had deaf parents, 15 had hearing parents
- *NVIQ*: deaf mean: 81.9th %ile (min: 25, max: 99); hearing mean: 78.9th %ile (min: 37, max: 99); there was no significant difference between the deaf and hearing groups ($U=224.0$, 2-tailed $p=.670$, NS)
- *Level of education*: All of the paired participants had intermediate/advanced or higher qualifications; 10 pairs had achieved higher level qualifications, 10 had achieved intermediate or advanced level qualifications, and three pairs were unmatched on this variable (in two of these pairs, the hearing participant had higher level qualifications and the deaf participant, intermediate/advanced)
- *Regional spoken accent*: 13 pairs had a similar regional spoken accent to the talkers, 7 had a different accent, and two pairs were unmatched on this variable (in one pair the deaf participant was from the same region as the talkers, and the hearing participant was not, and vice versa in the other pair)

For this reduced group, the TAS data remained normally distributed (Shapiro-Wilk statistic = .984, $p=.790$), and the variances homogenous ($F=.045$, $p=.833$). The deaf participants in this matched group outperformed the hearing ($t(42)=3.02$, 2-tailed



$p<.005$; see Figure 6.4).

Figure 6.4: Mean raw scores on the TAS for the matched deaf and hearing participants (error bars show a 95% confidence interval)

There was, then, a significant difference between the speechreading abilities of deaf and hearing people: deaf adults outperformed hearing adults on the TAS.

This finding prompts the question of whether there were subgroups of deaf or hearing participants who showed superior speechreading abilities. Specifically, did *parental* hearing status, which has an enormous impact on the early language development of both deaf and hearing children (see Chapter 2, sections D and F), also impact on their speechreading ability as adults? And what other factors, within the deaf group particularly, were associated with better speechreading skills? Could these account for the deaf group's superior speechreading performance? These questions are investigated in the following sections, in which the demographic characteristics of the participants are considered.

The distribution of participants could not be completely balanced across all of the variables, and the effect of one variable on speechreading performance may be confounded by others. Tables 6.4 and 6.5 therefore show the frequencies of hearing and deaf participants respectively as a function of a number of the demographic variables to be considered.

Table 6.4: Demographic breakdown of the 51 hearing participants by parental hearing status, gender, and education level (Higher: degree or equivalent; Inter.: GCSE to A-level or equivalent; Basic: entry level).

Parental Hearing Status		Gender		Education Level	
Hearing	41	Male	16	Higher	12
				Inter.	3
				Basic	1
		Female	25	Higher	16
				Inter.	9
Deaf	10	Male	2	Higher	2
		Female	8	Higher	1
				Inter.	6
				Basic	1

Table 6.5: Demographic breakdown of the 41 deaf participants by parental hearing status, use of hearing aids, preferred language (BSL alone / some English), language used at home during childhood, type of school (selective oral grammar / other oral / mainstream / Total Communication), gender, and education level (Higher: degree or equivalent; Inter.: GCSE to A-level or equivalent; Basic: entry level).

Parental Hearing Status		Use hearing aids?		Preferred Language		Childhood Language		Type of school		Gender		Education Level	
Hearing	23	No	11	BSL	10	Speech	5	Oral	3	F	2	Inter.	2
										M	1	Higher	1
								Mainstream	1	F	1	Higher	1
								TC	1	M	1	Inter.	1
						BSL	1	TC	1	F	1	Basic	1
						Higher	2						
						TC	1	F	1	Inter.	1		
												English	1
		Yes	12	BSL	6	Speech	3	Oral	3	F	2	Inter.	1
										M	1	Inter.	1
										BSL	1	Oral	1
						Mixture	2	Oral	1				
										TC	1	F	1
						English	6	Speech	6	Selective	3	F	1
				M	2							Higher	2
				Mainstream	3					F	3	Inter.	2
												Higher	1
				Deaf	18	No	7	BSL	6	BSL	5	Oral	3
M	2	Inter.	1										
TC	2	F	1									Higher	1
		M	1									Higher	1
Mixture	1	Oral	1					F	1	Inter.	1		
												English	1
Yes	11	BSL	7			BSL	5	Oral	3	M	2	Inter.	1
												Higher	1
								Mainstream	1	F	1	Inter.	1
Mixture	2			Selective	2	M	2	Higher	2				
										Speech	1	Oral	1
English	4	Speech	1	Oral	1	F	1	Inter.	1				
										Mixture	3	Oral	1
Selective	2	F	2	Inter.	2								

6.8 Are there subgroups of deaf or hearing participants with superior speechreading abilities?

6.8.i Parental hearing status

Eighteen of the deaf participants had deaf parents (DoD), and twenty-three, hearing parents (DoH). All of the DoD participants, and eight (35%) of the DoHs reported that the cause of their deafness was genetic. Both subgroups have relative advantages in terms of speechreading: those with deaf parents (DoD) are likely to have had a richer early language experience, resulting in superior literacy and cognitive abilities, and those with hearing parents (DoH) are likely to have had more exposure to proficiently spoken English during early childhood and a stronger early motivation to learn the speechreading skills needed to understand it (see Chapter 2, Section D).

Within the hearing group, ten participants had deaf parents (HoD), and forty-three, hearing parents (HoH). The HoD group were expected to outperform the HoH due to their increased awareness of visual communication (see Chapter 2, Section F). The groups' respective mean scores on the TAS are illustrated in Figure 6.5.

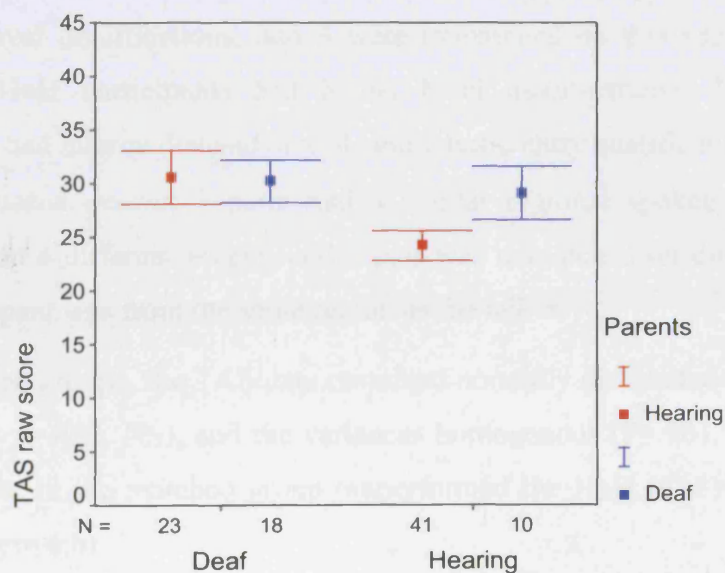


Figure 6.5: Performance of the deaf and hearing participants on the TAS as a function of parental hearing status (error bars show a 95% confidence interval)

Although the TAS core subtest data were normally distributed for both the deaf and hearing participants (see Appendix M), the variances of the groups categorised by parental hearing status were not homogenous ($F=3.49$, $p<.02$). Because of this violation of parametric assumptions, the performances of the four subgroups on the core TAS subtests were compared using Mann-Whitney tests. The hearing group

with hearing parents were outperformed by both of the deaf groups (DoH: $U=205.00$, 2-tailed $p<.001$, DoD: $U=131.50$, 2-tailed $p<.001$) and the HoD group ($U=88.50$, 2-tailed $p<.005$). There was no significant difference between these three groups. In other words, within the deaf group there was no difference in performance on the TAS core subtests as a function of parental hearing status. Within the hearing group, however, the participants with deaf parents outperformed those with hearing parents.

The difference between the HoH and HoD participants was further verified by reducing the variability between the groups as far as possible: the 10 participants with deaf parents were matched (as the deaf and hearing pairs had been, see pg. 173) on

- *Age*: HoH mean age: 34;3, HoD mean age: 32;8
- *Gender*: 2 pairs were male, 8 female
- *NVIQ*: HoH mean: 75.4th %ile (min: 37, max: 98); HoD mean: 69.0th %ile (min: 37, max: 98); there was no significant difference between the groups ($U=42.5$, 2-tailed $p=.565$, NS)
- *Level of education*: 3 pairs had higher level qualifications, 4 had intermediate or advanced level qualifications, and 3 were unmatched on this variable (in these pairs, the HoH participants had higher level qualifications, 2 of the HoD participants had intermediate/advanced, and 1 basic/entry qualifications)
- *Regional spoken accent*: 7 pairs had a similar regional spoken accent to the talkers, 2 had a different accent, and 1 pair was unmatched on this variable (the HoD participant was from the same region as the talkers)

For these reduced groups, the TAS data remained normally distributed (Shapiro-Wilk statistic = .956, $p=.473$, NS), and the variances homogenous ($F=.961$, $p=.340$). The HoD participants in the matched group outperformed the HoH ($t(18)=3.63$, 2-tailed $p<.005$; see Figure 6.6).

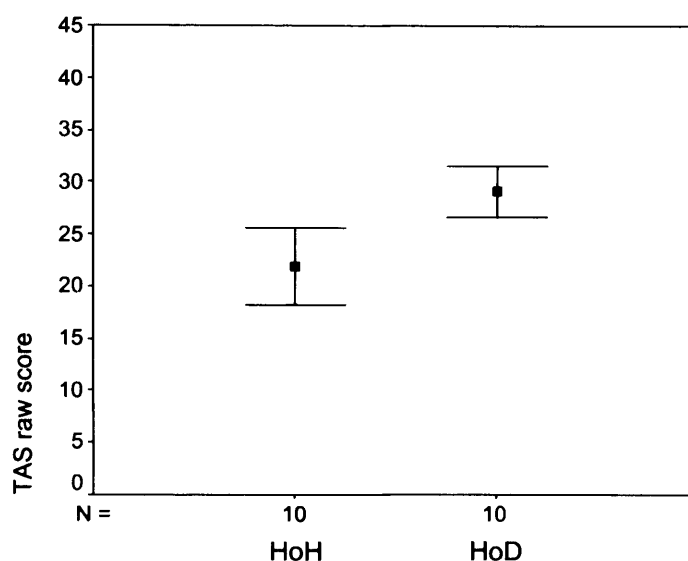


Figure 6.6: Mean raw scores on the TAS for the matched HoH and HoD participants (error bars show a 95% confidence interval)

Since the hearing participants with deaf parents speechread significantly better than those with hearing parents, the small HoD group is considered separately from the rest of the hearing group from this point forward.

A possible explanation for the HoD group's superior speechreading performance may lie in their occupations. While occupations within the other participant groups varied widely, Table 6.9 shows that 80% of the participants in the HoD group were employed facilitating communication between d/Deaf and hearing people. They are therefore likely to have a heightened awareness and knowledge of language and communication, including speechreading.

Table 6.9: The occupations of the HoD group

Occupation	Frequency
BSL interpreter	3
BSL interpreter & actress	1
Trainee BSL interpreter	1
Communication support worker	3
Administration	1
Customer services (airline)	1

The possibility that the superior speechreading skills of the HoD participants can be explained by their occupation was investigated in Study 6A.

STUDY 6A

**Investigation of the speechreading skills of
hearing late signers who work facilitating communication between
deaf and hearing people**

Introduction

Following the finding that a small group of HoD people were better speechreaders than HoH, the speechreading skills of a group of hearing participants who learnt BSL in adulthood and worked facilitating communication between deaf and hearing people (the HS group) were considered. If the HS group outperformed participants with no knowledge of BSL or experience of communicating with deaf people (the HoH group), as those with deaf parents (HoD) did, it would suggest that a heightened awareness and knowledge of language and visual communication, gained through extensive experience of communicating with deaf people, results in improved speechreading skills.

MethodsParticipants

Nine hearing adults with hearing parents who worked facilitating communication between deaf and hearing people and had learnt BSL in adulthood were recruited for this study. Two participants were BSL interpreters, two were communication support workers, three, teachers of the deaf, and two, support assistants in a unit for deaf children. No participant reported any additional disabilities, none scored lower than two standard deviations below the mean on the non-verbal IQ test, and all had normal or corrected-to-normal vision.

These participants were matched as far as possible to HoH participants from the main study. Table 6.7 shows their demographic characteristics.

Materials

All participants completed the background questionnaire (Appendix F), the Test

of Adult Speechreading (TAS) core subtests (see Chapter 5), and the block design task from the Weschler Adult Intelligence Scale – revised (WAIS-R, Wechsler 1981)

Table 6.7: Demographic characteristics of the hearing late signers (HS) and the matched non-signing (HoH) participants

		HS	HoH
Age	Mean (yrs;mths)	42;5	44;0
	Range (yrs;mths)	27;9 – 52;3	28;7 – 54;7
Gender	Male (N)	2	5
	Female (N)	7	4
NVIQ	Mean (%ile)	85.2	82.2
	S.D.	12.37	11.30
Education level	Higher (N)	6	7
	Intermediate/advanced (N)	3	2
Age when started to learn BSL	Mean (years)	32.3	--
	Range (years)	16 - 50	--

Results

The TAS data were normally distributed (Shapiro-Wilk statistic = .939, $p=.275$, NS), and the variances homogenous ($F=1.603$, $p=.224$, NS).

The HS group scored slightly higher on the TAS than the HoH group. The mean TAS score for the HS group was 25.89; the mean for the matched HoH participants was 22.78. Their speechreading performance is illustrated in Figure 6.7. The difference between the groups did not reach significance ($t(16)=1.75$, 2-tailed $p=.099$, NS).

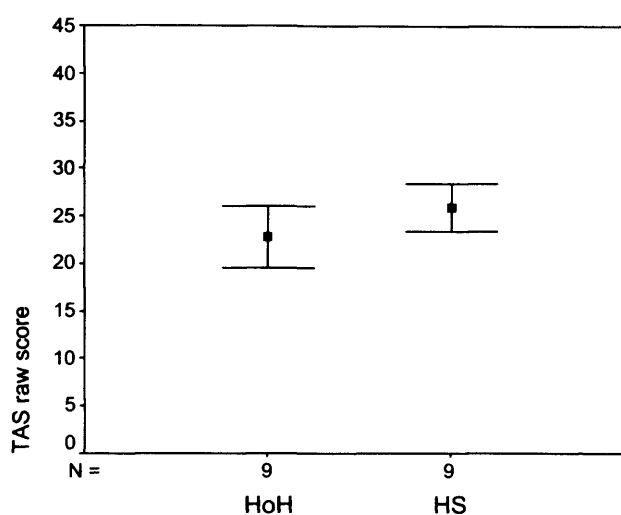


Figure 6.7: Mean raw scores on the TAS for the matched HoH and HS participants (error bars show a 95% confidence interval)

Discussion

The slightly higher speechreading scores achieved by this small group of late-signing hearing participants who work facilitating communication between deaf and hearing people suggests that a heightened awareness and knowledge of language and communication could result in improved speechreading scores. However, the difference did not reach significance. The significantly superior speechreading scores achieved by hearing people with deaf parents are unlikely, therefore, to be a result of their employment alone. Rather, experience of communicating with deaf people throughout childhood and during the development of language is hypothesised to result in superior speechreading skills. Larger participant groups and longitudinal studies are needed to further investigate this issue.

6.8.ii Deaf-specific Demographic Variables

To investigate whether subgroups of deaf participants showed superior speechreading skills, the following factors were considered:

- Use of hearing aids
- Language Preference
- Language used when growing up
- School type
- Age at first exposure to BSL

6.8.ii.a) Use of hearing aids

It was hypothesised that deaf participants who use hearing aids would achieve higher speechreading scores than those who do not. Twenty-three of the deaf group reported using at least one hearing aid, and eighteen reported no longer using them (all had to wear hearing aids in school). There was no difference in hearing aid use between the DoH and DoD groups (see Tables 6.5 and 6.8, $\chi^2=.567$, $p=0.75$).

Table 6.8: Crosstabulation of number of deaf participants with deaf and hearing parents, and the number who do and who do not wear hearing aids

	DoH	DoD	Total
D (no aids)	11	7	18
D (aids)	12	11	23
Total	23	18	41

As expected, given the advances in hearing aid technology, the hearing aid users were significantly younger than the other participants (see Figure 6.8, $t(39)=2.75$, 2-tailed $p<.01$).

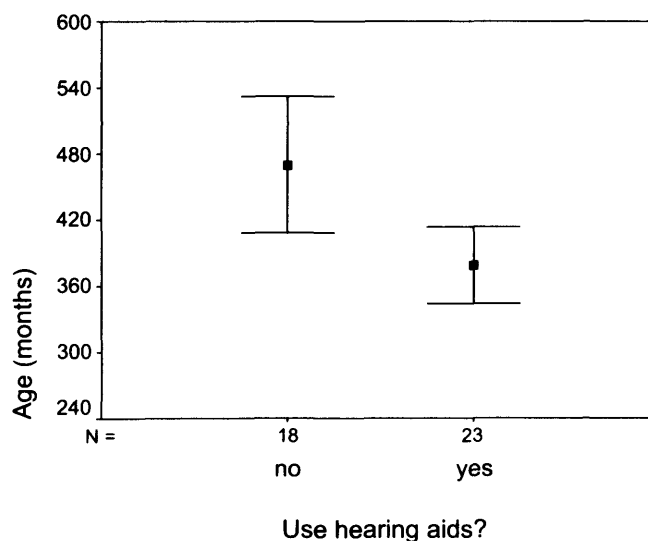


Figure 6.8: Comparison of the ages of the deaf participants who wore hearing aids and those who did not (mean age in months with 95% confidence intervals)

The participants who used at least one hearing aid significantly outperformed those who do not on the TAS ($t(39)=3.25$, 2-tailed $p<.005$; see Figure 6.9). This difference remained significant when age was controlled for ($F=9.495$, 2-tailed $p<.005$). The hypothesis that hearing aid users would speechread better than non-users was therefore supported.

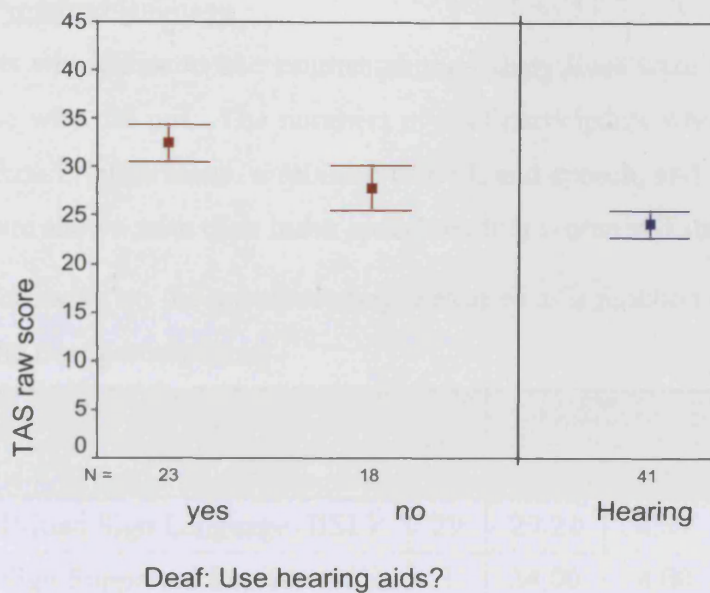


Figure 6.9: Comparison of the performance on the TAS of the deaf participants who wore hearing aids, those who did not, and the hearing (HoH) participants (mean scores with 95% confidence intervals).

The superior speechreading performance of the deaf participants on the TAS shown in section 6.13 did not reflect only the performance of those who wear hearing aids. Figure 6.9 shows the performance of the deaf participants grouped by whether or not they choose to wear hearing aids, and of the hearing (HoH) participants. It can be seen that both of the deaf groups speechread significantly better than the HoH group (without aids: $t(57)=2.82$, 2-tailed $p<.01$; with aids: $t(62)=7.09$, 2-tailed $p<.001$).

Sixteen of the participants who did not wear hearing aids reported the age at which they ceased hearing aid use. This varied from 16 to 38 years old (mean age: 20 yrs 9 mths; all participants had to wear hearing aids at school). The participants had spent between 5 and 44 years without aids (mean: 18 yrs 8 mths). There was no correlation between the number of years without hearing aids and speechreading performance (Spearman's $\rho = -.077$, 2-tailed $p=.776$).

Summary: Participants who wore hearing aids outperformed those who did not on the TAS. The aided group's superior performance did not account for the deaf participants' overall speechreading superiority over the hearing participants since those who did not wear aids also performed better on the TAS than the HoH participants. Within the unaided group, there was no relationship between the number of years without aids and speechreading performance.

6.8.ii.b) Preferred language

Deaf participants who chose to use English in their daily lives were hypothesised to outperform those who did not. The numbers of deaf participants who reported using BSL alone, spoken English alone, a mixture of BSL and speech, and Sign Supported English (SSE), are shown with their mean speechreading scores in Table 6.9.

Table 6.9: Performance on the speechreading measures as a function of the language preferences of the deaf participants

Preferred Language	N	TAS raw score	
		Mean	S.D.
British Sign Language (BSL)	29	29.21	4.89
Sign Supported English (SSE)	3	34.00	4.00
BSL / Speech mixture	6	30.67	2.50
English (Speech)	3	38.33	2.89

It can be seen that the three deaf participants who used speech alone in their everyday lives achieved the highest mean speechreading scores. These group numbers were too small to compare statistically; the participants who chose to use any English in their everyday lives were therefore combined into one group for comparison with those who chose to use British Sign Language (BSL) alone.

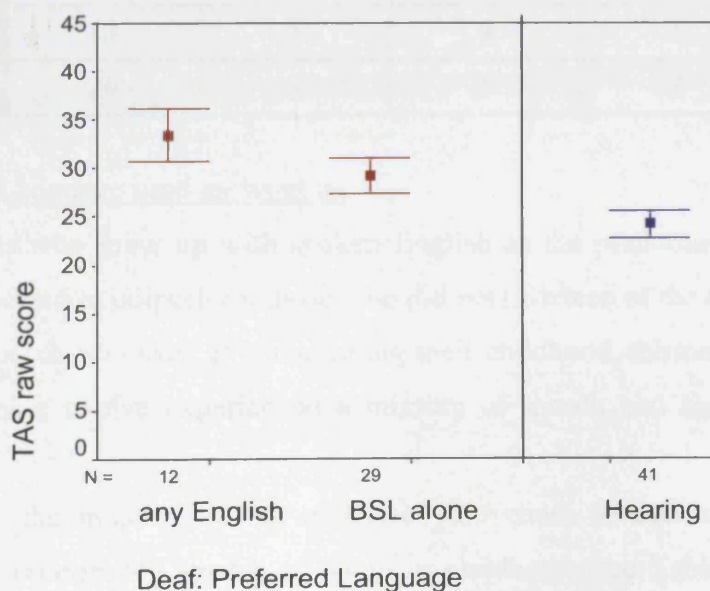


Figure 6.10: Comparison of the speechreading performance of the deaf participants who preferred to use some English in their everyday lives, those who used BSL alone, and the hearing (HoH) participants (error bars show a 95% confidence interval)

As Figure 6.10 shows, the 12 participants who preferred to use some English performed significantly better than those who did not on the TAS ($t(39)=2.60$, 2-tailed $p<.02$).

Again, the superior performance of the deaf participants who used some English did not explain the speechreading superiority of the deaf group as a whole. The participants who chose to use BSL alone still outperformed the hearing (HoH) participants ($t(68)=4.41$, 2-tailed $p<.001$).

The language and cultural choices that deaf individuals make are naturally interrelated, so it is unsurprising that their reported preferred language was not independent of their choice of whether or not to use hearing aids. Significantly more of the participants who chose to wear hearing aids also chose to use some English (speech, a mixture of speech and BSL, or SSE) in their everyday lives ($\chi^2=5.11$, 2-tailed $p<.05$). Table 6.10 shows the number of participants in each subgroup who reported preferring each language choice.

Table 6.10: Crosstabulation of the language choices of deaf participants who did and did not wear hearing aids

	BSL	Speech	BSL/speech mixture	SSE	Total
D (no aids)	16	0	2	0	18
D (aids)	13	3	4	3	23
Total	29	3	6	3	41

6.8.ii.c) Language used growing up

The participants who grew up with spoken English as the predominant language at home were expected to outperform those who did not. Sixteen of the deaf participants reported that speech was used at home during their childhood, thirteen reported BSL, and the remaining twelve experienced a mixture of speech and sign as they were growing up.

Unsurprisingly, the majority (67%) of those who chose to use some English in adulthood had experienced speech at home in childhood (see Table 6.11), and all except one of those who experienced BSL when they were growing up (85% of whom had deaf parents, see Table 6.5, pg. 175) chose to use BSL in adulthood. The statistical significance of these proportional differences could not be assessed with

chi-squared tests because the small numbers would have resulted in too great a proportion of expected frequencies smaller than 5.

Table 6.11: Crosstabulation of the language used in growing up, and the preferred language in adulthood

		Preferred Language in adulthood		<i>Total</i>
		BSL alone	Any English	
Language used in childhood	BSL	12	1	13
	Mixture	9	3	12
	Speech	8	8	16
	<i>Total</i>	29	12	41

The speechreading performance of the three subgroups of deaf participants on the TAS is shown in Figure 6.11.

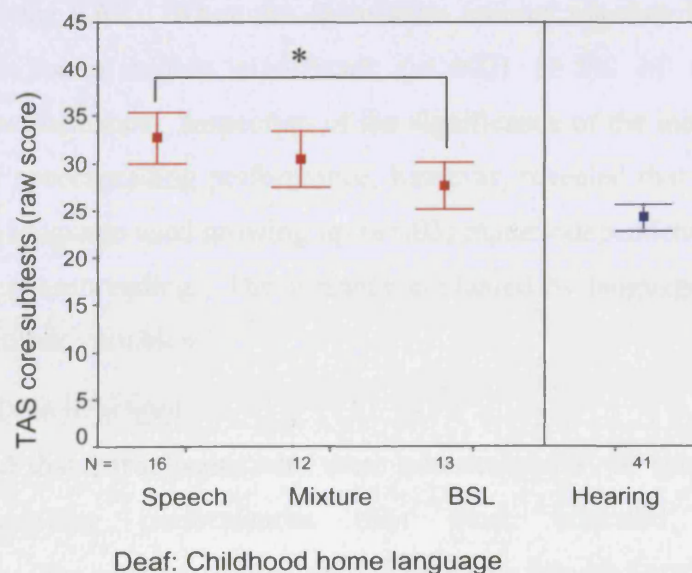


Figure 6.11: Comparison of the speechreading performance of the deaf participants sub-grouped by their childhood home language, and the hearing (HoH) participants (error bars show a 95% confidence interval; * difference significant at $p < .01$)

As hypothesized, there was significant effect of childhood home language on speechreading performance ($F_{(2,38)}=4.04$, $p < .05$). Planned contrasts showed that those who grew up using speech in the home outperformed those who used BSL at home ($t(38)=2.84$, 2-tailed $p < .01$). The performance of those who experienced a mixture of sign and speech fell between the other two groups, and was not significantly different

from either. All the subgroups significantly outperformed the hearing participants (BSL: $t(52)=2.48$, 2-tailed $p<.02$).

Summary: The deaf participants who used hearing aids, who experienced English at home during childhood, or who chose to use some English in adulthood outperformed the other deaf participants on the TAS. This did not account for the whole deaf group's superior performance in comparison to that of the hearing group: in each case the poorer performing deaf group outperformed the HoH participants. Language preference was related to early language experience and hearing aid use for the deaf participants: more of those who used aids, or who experienced English at home during childhood, chose to use some English in adulthood.

Multiple regression analyses were conducted to investigate whether these three variables (use of hearing aids, preferred language (BSL alone or some English), and childhood home language) explained independent variance in speechreading performance on the TAS. When the three were entered together into the analysis, they accounted for a highly significant ($p<.002$) 35.5% of the variance in speechreading performance. Inspection of the significance of the individual variables as predictors of speechreading performance, however, revealed that only hearing aid use ($p<.02$) and language used growing up ($p<.05$) made independent contributions to the variance in speechreading. The variance explained by language preference was shared with the other variables.

6.8.ii.d) Type of school

It was predicted that participants who were educated orally at school would show higher speechreading performances than those educated through Total Communication. The number of deaf participants who reported attending a selective oral grammar school, other oral schools, mainstream schooling, and Total Communication schools are shown in Table 6.12.

Table 6.12: The type of schools attended by the deaf participants

Type of School Attended	No. of Participants
Selective oral	10
Other oral	20
Mainstream	5
Total Communication	6

It can be seen that, consistent with the nature of schooling systems for deaf children when these adults were growing up, the majority of the individuals who participated in this study had been educated orally, and a minority of these had attended at a selective grammar or mainstream school; few participants had been educated in a Total Communication environment.

There was a significant group effect of school type on speechreading performance on the TAS ($F=3.37$, $p<.05$; see Figure 6.12). Post-hoc Games-Howell tests (selected because of the different sample sizes) showed that the participants who attended a selective grammar school performed significantly better on the TAS than those who attended other oral schools (2-tailed $p<.05$). No other differences reached significance.

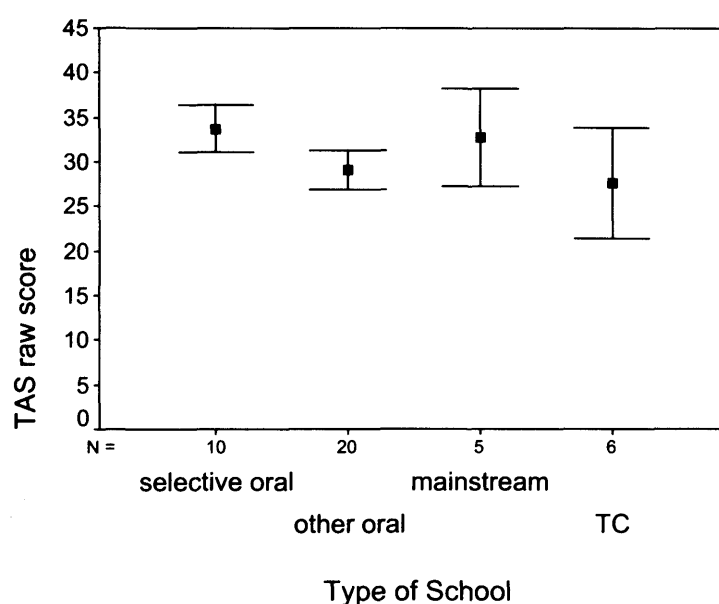


Figure 6.12: Comparison of the speechreading performance of deaf participants grouped by type of school attended (error bars show a 95% confidence interval)

As expected within the 'other oral' group, the 5 participants aged under 30 years performed significantly better than the 15 older participants (aged 30;1 to 56;11; $t(18)=1.96$, 1-tailed $p<.05$). This is likely to reflect changes in oral education practices (see Chapter 2, Section C).

Admittance to selective grammar schools is dependent on ability, and ex-pupils may therefore have been predicted to outperform those who attended other oral schools as a result of their higher general intelligence and language abilities. The participants who had attended a selective oral school did have a significantly higher mean non-verbal IQ than those who had attended other oral schools ($U=52.5$, $n=30$, 2-tailed

$p<0.05$), however the group effect of school type on TAS score survived when non-verbal IQ was controlled for ($F=2.87$, $p<.05$). This suggested that the superior speechreading performance of those who attended a selective grammar school over those who attended other oral schools was not due to their higher general intelligence. The type of schooling received by deaf individuals may be expected to have influenced their later language and cultural choices. Table 6.13 shows the number of deaf participants, sub-grouped by the type of school they attended, who chose to wear hearing aids, and Table 6.14 the number who used only BSL or some English in their daily lives.

Table 6.13: Crosstabulation of the number of deaf participants who did and did not wear hearing aids who attended different school types

	Selective oral	Other oral	Mainstream	TC	Total
D (no aids)	2	10	1	5	18
D (aids)	8	10	4	1	23
Total	10	20	5	6	41

Table 6.14: Crosstabulation of the language choices of deaf participants who attended different school types

	Selective oral	Other oral	Mainstream	TC	Total
BSL alone	3	18	2	6	29
Any English	7	2	3	0	12
Total	10	20	5	6	41

The statistical significance of the proportional differences could only be assessed with chi-squared tests for the participants who attended selective oral and other oral schools; inclusion of the smaller groups would have resulted in too great a proportion of expected frequencies smaller than 5. Significantly more of the participants who had attended a selective oral school (rather than a non-selective oral school) chose to use some English (speech, a mixture of speech and BSL, or SSE) in their everyday lives (see Table 6.14; $\chi^2=4.80$, 2-tailed $p<.05$). The majority of these participants (80%, see Table 6.13), also chose to use hearing aids. However, there was no significant difference between the proportion of those who used aids who had attended 'selective oral' and 'other oral' schools respectively ($\chi^2=1.20$, 2-tailed $p=.273$, NS).

The group effect of school type on TAS score did not reach significance when language preference was controlled for ($F=1.27$, $p=.301$, NS). Type of school attended did not therefore make an independent contribution to speechreading performance. The superior speechreading skills of the participants who had attended a selective oral grammar school over those who had attended other oral schools reflected the greater proportion of those in the former subgroup who chose to use some English in their adult everyday life.

6.8.ii.e) Age at first exposure to BSL

As expected (see Chapter 2, Section D), participants with deaf parents were exposed to BSL significantly earlier than those with hearing parents ($U=13.5$, $n=41$, 2-tailed $p<.001$), and age at diagnosis correlated significantly with age at first exposure to BSL (Spearman's $\rho = .50$, $n=28$, 2-tailed $p<.01$). That is, the earlier individuals were diagnosed as deaf, the earlier they were exposed to BSL. Speechreading performance was expected to be positively correlated with age at first exposure to BSL: the later an individual was exposed to BSL, the better their speechreading performance was predicted to be (see section 2.9). This hypothesis was not supported. There was no correlation between age at exposure to BSL and performance on the TAS (Spearman's $\rho = .11$, $n=41$, 2-tailed $p=.507$).

6.8.ii.f) Summary

Subgroups of deaf participants who showed superior speechreading ability on the TAS were characterized by

- Hearing aid use: those who chose to wear aids showed superior performance
- Preferred language: those who used some English (spoken or SSE) in their daily lives showed superior performance
- Language used when growing up: those who grew up with spoken English being used in the home showed superior performance
- Schooling: those who attended a selective oral grammar school showed superior performance

These subgroups of superior deaf speechreaders did not account for the overall finding that deaf people were better at speechreading than hearing people. In each case, the poorer-performing subgroup outperformed the HoH group.

It is notable that age at exposure to British Sign Language did not affect speechreading performance. It is likely that, while proficiency in English enhances speechreading ability, BSL does not impact on it.

Of the deaf-specific variables that were expected to influence speechreading ability, only hearing aid use and childhood language experience had independent effects on performance on the TAS.

6.8.iii Other Demographic Variables

The following demographic variables are hypothesised to affect speechreading for both deaf and hearing people:

- Gender
- Age
- Level of education
- Personality: risk-taking & impulsiveness

6.8.iii.a) Gender

Fifteen (36.6%) of the deaf participants and sixteen (39%) of the hearing (HoH) were male. Female speechreaders were expected to outperform males in both the deaf and hearing groups (see section 6.3.i). The speechreading performance of participants in both groups is shown in Figure 6.13 as a function of gender.

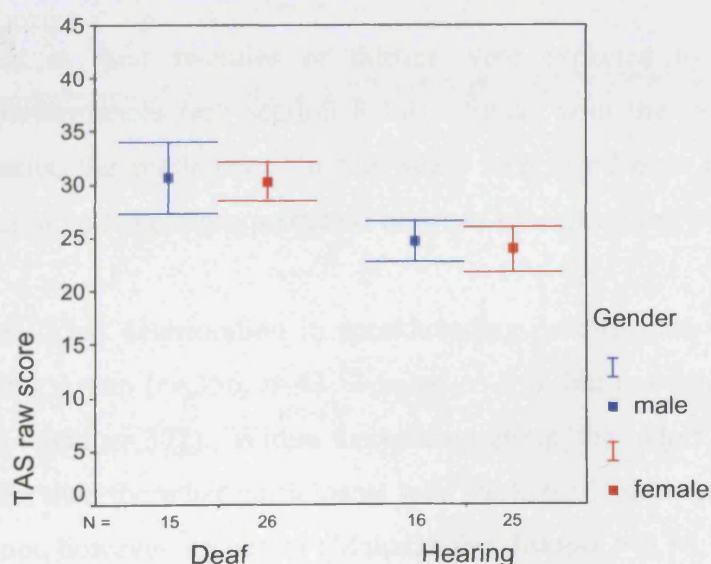


Figure 6.13: Performance of male and female deaf and hearing (HoH) participants on the TAS (error bars show a 95% confidence interval)

The hypothesis that females are better speechreaders than males was not supported: there was no significant difference between the performances of this sample of male and female speechreaders on the TAS for either the deaf²³ ($U=180.5$, $n=41$, $p=.694$, NS) or the HoH group ($t(39)=.483$, $p=.632$, NS).

6.8.iii.b) Age

Table 6.15 shows the descriptive statistics for the ages of the deaf and hearing groups. There was no significant difference between the two groups as a function of their ages ($U^{24}=720.5$, $p=.266$), but there was a greater range of ages in the hearing group.

Table 6.15: Descriptive age statistics (yrs;mths) for the deaf and hearing (HoH) groups

	Min.	Max.	Mean	S.D.
Deaf	21;5	60;1	34;11	9.20
Hearing	16;0	76;1	34;7	13.37

Table 6.16 shows the frequencies of the deaf and hearing (HoH) participants categorised by age group, and the distribution of the participants in each age group with respect to their gender, and for the deaf participants, their hearing aid use and preferred language. It can be seen that, as expected, the hearing aid users were all young adults: 21 of the 23 hearing aid users were in their 20's or 30's. The oldest was 43 years old.

Participants aged in their twenties or thirties were expected to show optimal speechreading performances (see section 6.3.ii). Since, with the exception of two hearing participants, the participants in this study were aged over twenty years, a negative correlation was therefore predicted between speechreading performance and age.

There was a significant deterioration in speechreading performance with increasing age for the hearing group ($r=.356$, $n=41$, 2-tailed $p<.05$), but not for the deaf group ($r=.142$, $n=41$, 2-tailed $p=.377$). Within the hearing group, the oldest participant was considerably older than the other participants (see Table 6.16 and Figure 6.14). This participant was not, however, an outlier (Mahalanobis distance = 3.88; with the use of a $p<.01$ criterion for Mahalanobis distance no multivariate outliers were identified),

²³ Mann-Whitney used because data violates parametric assumption of homogeneity of variance ($F=4.86$, $p<.05$)

²⁴ Mann-Whitney used because data violates parametric assumption of homogeneity of variance ($F=5.55$, $p<.05$)

and did not substantially influence the model parameters (Cook's distance = .142; standardised DFBeta values < 1).

The pattern of correlations suggests that speechreading skill, as measured by the TAS (on which the deaf participants outperformed the hearing), is less susceptible to deterioration with age in deaf adults.

Table 6.16: Frequencies of participants grouped by age (in years), showing the distribution of these as a function of gender, and, for the deaf groups, hearing aid use and preferred language (BSL alone / some English).

Group	Gender	Aids	Language	teens	20s	30s	40s	50s	60s	70s
DoH	Male	No	BSL			1	1			
			English				1			
		Yes	BSL			1	1			
			English			2				
	Female	No	BSL		1	4	2		1	
			BSL		1	3				
		Yes	English		1	3				
DoD	Male	No	BSL			2		1		
			BSL		4					
		Yes	English				1			
	Female		No	BSL		1	1		1	
		English			1					
		Yes	BSL		1	2				
			English		2	1				
			Deaf totals				0	12	20	6
HoH	Male			1	7	5	2	1		
	Female			1	13	3	1	6		1
HoH totals				2	20	8	3	7	0	1
TOTALS:				2	32	28	9	9	1	1

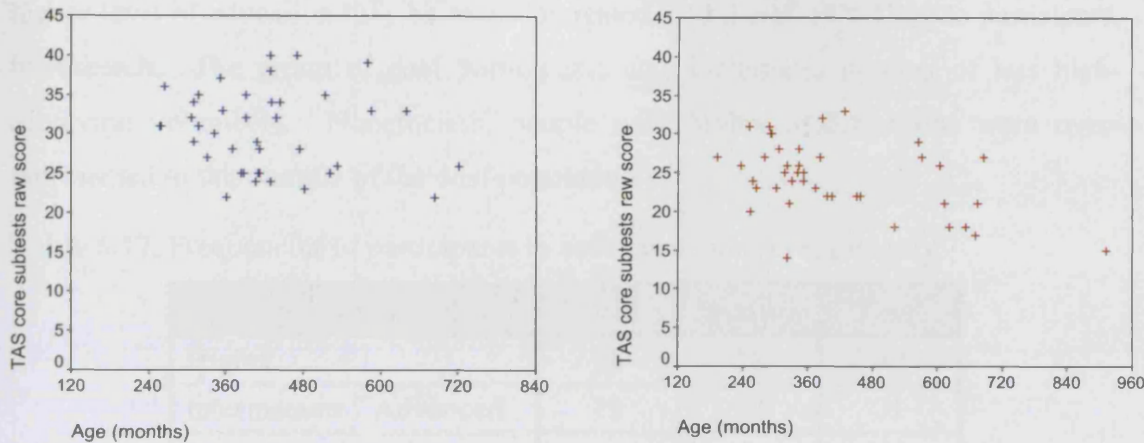


Figure 6.14: Correlation between performance on the TAS core subtests and age for the deaf (left) and hearing (HoH, right) participants

6.8.iii.c) Non-verbal IQ and Level of Education

In line with previous findings (see section 6.3.iii), it was predicted that there would be a positive, but non-significant, relationship between speechreading and non-verbal IQ. A measure of non-verbal IQ was obtained using the block design task from the Wechsler Adult Intelligence Scales (Wechsler 1981).

As expected, the correlation between non-verbal IQ and speechreading performance on the TAS did not reach significance for the deaf ($r = .205$, $n=41$, 2-tailed $p=.198$) or hearing (Spearman's $\rho = .189$, $n=41$, 2-tailed $p=.237$) participants, or for the groups combined (Spearman's $\rho = .136$, $n=82$, 2-tailed $p=.225$).

Speechreaders with higher levels of education were predicted to outperform those with lower levels within the deaf (but not the hearing) group because superior English language skills facilitate progression in the education system.

Participants were placed into three education level categories on the basis of their responses to the background questionnaire. Those who had achieved a degree or equivalent (e.g. NVQ level 4 or 5) were categorised as 'higher', those with qualifications equivalent to GCSE-level or above (but below the higher-level qualifications), as 'intermediate / advanced', and those who had not achieved qualifications equivalent to GCSE-level, as 'basic / entry'. Table 6.17 shows the frequencies of deaf and hearing participants in each education level category.

Although only a small percentage of deaf people attend higher education (RNID 2003b; see section 6.3.iii), over half (51.2%) of the deaf participants included in this thesis had achieved degree-level qualifications. It is possible that people with a

higher level of education may be more interested, and therefore willing to participate, in research. The group of deaf participants also included a number of less high-achieving volunteers. Nonetheless, people with higher qualifications were over-represented in this sample of the deaf population.

Table 6.17: Frequencies of participants in each education level category

Education Level	Deaf	Hearing	Total
Higher	21	28	49
Intermediate / Advanced	19	12	31
Basic / Entry	1	1	2

The number of participants in the 'Basic / Entry' category was too small to compare to the other groups statistically. They were therefore combined with the 'Intermediate / Advanced' group. The speechreading performance of the deaf and hearing (HoH) 'Higher' and the collapsed 'below Higher' subgroups is shown in Table 6.18. There was no significant difference between the subgroups' scores on the TAS for either the deaf ($t(39)=.415$, $p=.680$, NS) or hearing ($t(39)=1.472$, $p=.149$, NS) participants. The hypothesis of an increase in speechreading ability with increasing educational level was not therefore supported. Further, this null finding suggests that, although many of the deaf participants are relatively high-achieving, their speechreading skills are representative of less high-achieving deaf adults. The high proportion of tertiary educated deaf participants does not explain the finding that the deaf group outperformed the hearing on the TAS.

Table 6.18: The speechreading performance of participants who have 'higher' level qualifications, and those who have below higher ('basic / entry', or 'intermediate / advanced') level qualifications

	Education level	N	Mean	S.D.
Deaf	Higher	21	30.76	5.33
	Below higher	20	30.10	4.86
Hearing	Higher	28	24.89	4.29
	Below higher	13	22.69	4.80

6.8.iii.d) Risk-taking & Impulsiveness

It was predicted that deaf (but not hearing) participants who were more risk-taking and impulsive would achieve higher speechreading scores, and that this measure

would correlate most strongly with the connected speech level of the TAS (see section 6.3.iv). Twenty of the deaf participants and eighteen of the hearing (11 HoH and 7 HoD) completed the risk-taking and impulsivity questionnaire²⁵. For this measure the results for the whole hearing group (HoH and HoD) were analysed in addition to the HoH group alone because the number of HoH participants who completed this measure was small, and the planned analyses were correlations.

The groups' risk-taking & impulsiveness scores are illustrated in Figure 6.15. Although the deaf group showed a slightly higher mean score on this measure (that is, were slightly more risk-taking and impulsive) than the hearing groups, there was no significant difference between them ($F_{(2,34)}=.918, p=.409, ns$).

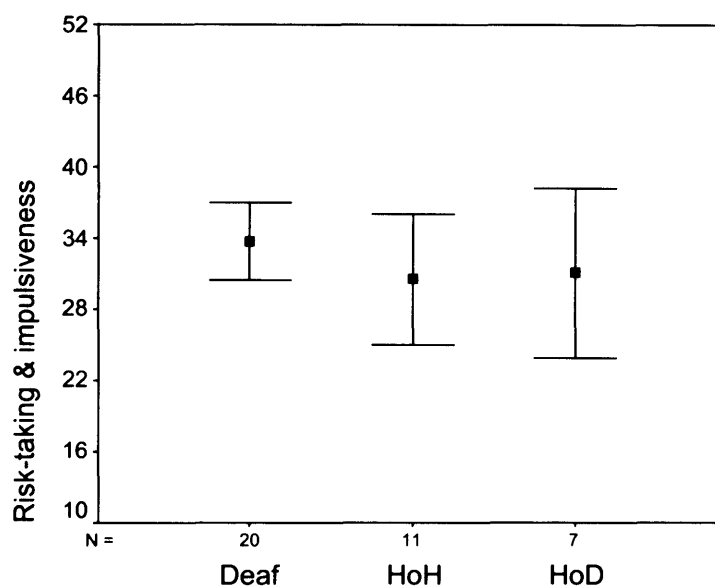


Figure 6.15: Mean risk-taking and impulsivity scores for the deaf and hearing (HoH and HoD) participants (error bars show a 95% confidence interval)

Inspection of the scatter graphs of performance on the TAS core subtests against risk and impulsiveness (Figures 6.16 and 6.17) showed an outlier in the deaf group (studentized deleted residual = 3.48, standardised DFBeta values > 1; circled in red in Figure 6.16). With this outlier (who was an exceptional speechreader) excluded, there was a significant positive correlation between speechreading (as measured by performance on the TAS) and degree of impulsiveness and willingness to take risks in the deaf group ($r = .554, n=19, p<.02$) as predicted. Also as predicted, when the subtests of the TAS were considered separately with respect to this variable, the

²⁵ The TAS data remained normally distributed for these reduced groups

correlation was only significant for the connected speech (story) level ($r = .534$, $n=19$, 2-tailed $p<.02$). The excluded participant (DoH 02) is considered further in Chapter 10.

As predicted, there was no relationship between risk-taking & impulsiveness and performance on the TAS for the hearing group as a whole or for the HoH group alone (HoH & HoD: $r = .135$, $n= 18$, $p=.594$, ns; HoH: $r = .081$, $n= 11$, $p=.813$, ns; see Figure 6.17).

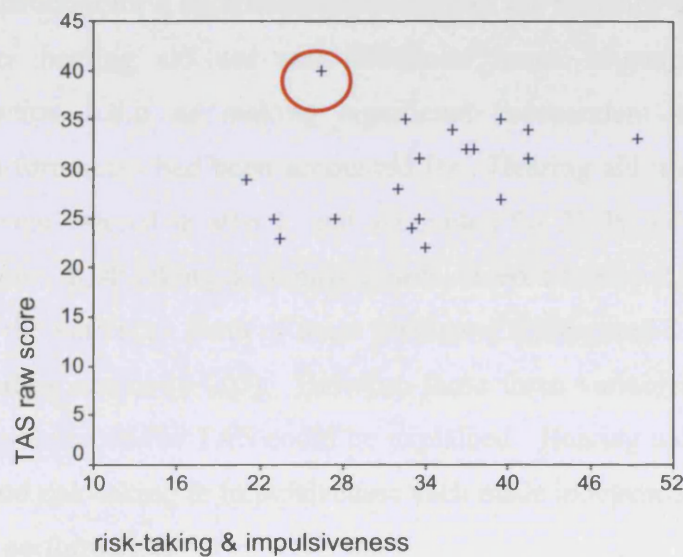


Figure 6.16: The relationship between speechreading performance on the TAS and risk-taking & impulsiveness for the deaf participants (outlier circled in red)

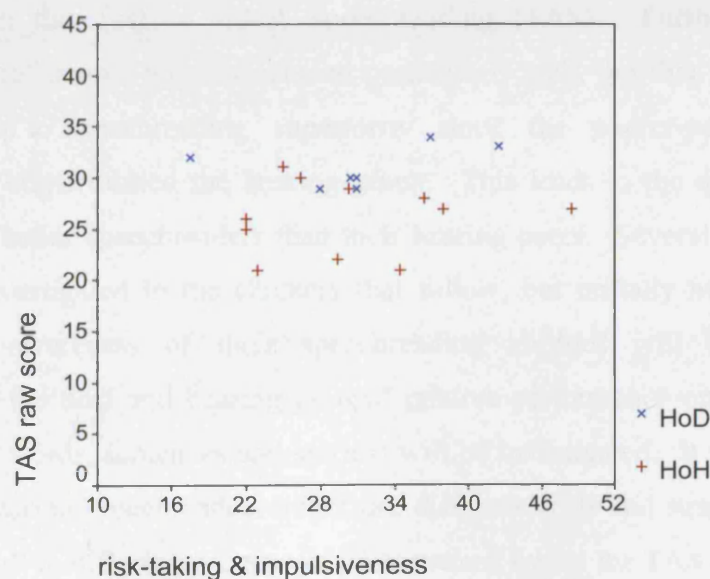


Figure 6.17: The relationship between speechreading performance on the TAS and risk-taking & impulsiveness for the hearing (HoH & HoD) participants

6.8.iii.e) Summary

There was no difference in speechreading skill as a function of gender, non-verbal IQ or education level for the deaf or hearing participants. Increasing age was associated with a decrease in speechreading performance only in the hearing group. Risk-taking and impulsiveness, on the other hand, was related to speechreading only in the deaf group.

A fixed order multiple regression analysis was conducted to see whether risk-taking & impulsiveness accounted for a significant proportion of the variance in speechreading performance after hearing aid use and childhood home language (which were identified in section 6.8.ii as making significant independent contributions to speechreading performance) had been accounted for. Hearing aid use and childhood home language were entered in step 1, and accounted for 27.4% of the variance in speechreading score. Risk-taking & impulsiveness, entered in step 2, accounted for a further 18.7% of the variance. Both of these predictors represented a moderate effect on the speechreading scores ($p < .05$). Between these three variables, 46.1% of the variance in performance on the TAS could be explained. Hearing aid use, childhood home language and risk-taking & impulsiveness each made independent contributions to speechreading performance.

So far, regarding the comparison of deaf and hearing adults' speechreading abilities, this chapter has established that deaf people speechread better than hearing people when tested on the Test of Adult Speechreading (TAS). Further, there were subgroups of deaf people who speechread particularly well, but this did not explain the deaf group's speechreading superiority since the poorer-performing deaf subgroups still outperformed the hearing group. This leads to the question of *why* deaf adults are better speechreaders than their hearing peers. Several aspects of this question are investigated in the chapters that follow, but initially here the groups' relative overt awareness of their speechreading abilities will be considered. Following this, the deaf and hearing groups' relative performance on the three core subtests (single words, sentences and stories) will be investigated. It was anticipated that deaf and hearing speechreaders might use different skills and strategies, and that these might result in differing patterns of performance across the TAS subtests for the two groups.

6.9 Are deaf adults better than hearing adults at rating their speechreading ability?

Deaf people have previously been found to be more accurate judges of their own speechreading performance on a subjective confidence rating scale than hearing people (Demorest & Bernstein 1997). The deaf participants in this study were, accordingly, predicted to be able to rate their speechreading ability more accurately than the hearing group. All of the deaf participants (N=41) and 26 of the hearing participants subjectively rated their speechreading ability on a ten-point scale where 1 was 'very poor' and 10 was 'very good'. As expected, the deaf participants rated their speechreading ability higher than the hearing participants ($U=101.0$, $p<.001$; see Figure 6.18).

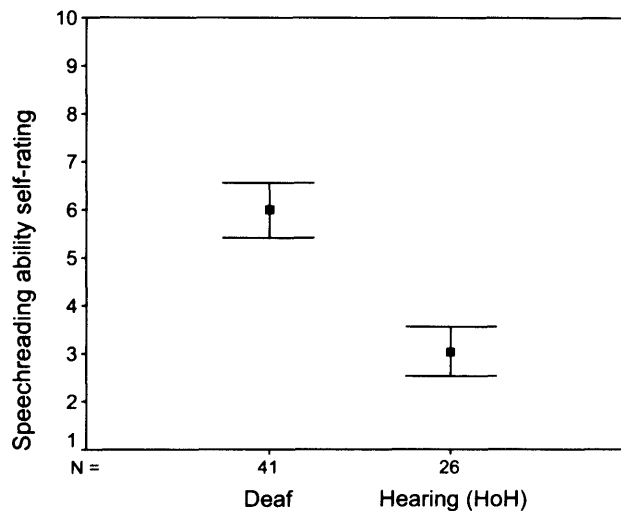


Figure 6.18: Mean subjective ratings of speechreading ability with 95% confidence intervals for deaf and hearing (HoH) participants

For the deaf group, there was a significant correlation between participants' subjective rating of their speechreading ability and their performance on the TAS core subtests (Spearman's $\rho = .571$, 2-tailed $p<.001$ see Figure 6.19). This correlation remained significant when non-verbal IQ was controlled for ($r=.575$, d.f.=38, 2-tailed $p<.001$). For the hearing group, the correlation did not reach significance (Spearman's $\rho = .254$, 2-tailed $p=.210$, NS; see Figure 6.19). The hypothesis that deaf people are able to rate their speechreading ability more accurately than hearing people was therefore supported.

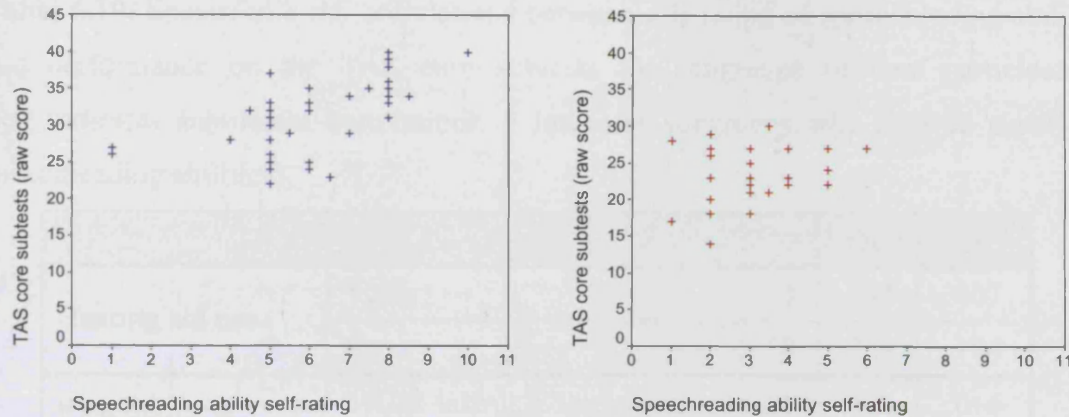


Figure 6.19: Correlation between self-rating of speechreading ability and speechreading accuracy on the TAS core subtests for the deaf (left) and hearing (HoH, right) participants

Further, within the deaf group the subgroups of deaf participants who were expected to make more everyday use of speechreading, and correspondingly showed superior performance on the TAS (e.g. those who chose to wear hearing aids) were able to rate their speechreading ability more accurately than other deaf participants (see Table 6.19). In each case where a subgroup showed significantly superior speechreading abilities (indicated by * in Table 6.19, see section 6.14), they were also better able to rate their speechreading ability than the rest of the deaf participants. For the subgroups with poorer speechreading performance, the correlation between self-rating and performance did not reach significance in the majority of cases. The only exception was for those whose preferred language was BSL. Comparing the correlation coefficients (using the Fisher Z-transform; Papoulis 1990) for these participants and those who preferred to use some English, however, showed that the correlation was significantly stronger for the latter ($p < .02$).

There was no difference in the strength of the correlations between speechreading self-rating and performance for factors that did not impact on speechreading performance (e.g. gender, education level; see Table 6.19), with one exception: deaf participants with hearing parents (the DoH group) were able to rate their speechreading performance more accurately than those with deaf parents (the DoD group).

Table 6.19: Spearman's rho correlations between self-rating of speechreading ability and performance on the TAS core subtests for subgroups of deaf participants (red indicates significant correlations, * indicates subgroups who showed superior speechreading abilities)

		N	rho	p	
Hearing aid use	* Yes	23	.544	.007	
	No	18	.328	.184	
Risk-taking & impulsiveness	* Risk-taking & impulsive	11	.700	.016	
	Careful & controlled	9	.017	.965	
Childhood home language	* Speech	16	.692	.003	
	BSL	13	.432	.141	
	Mixture	12	.447	.146	
Type of school	* Oral	Selective grammar	10	.644	.044
		Mainstream	5	.894	.041
		Other oral	20	.519	.019
	TC	6	-.058	-.058	
Preferred language	* Some English	12	.909	.000	
	BSL	29	.492	.007	
Parental hearing status	Hearing	23	.662	.001	
	Deaf	18	.382	.117	
Gender	Male	15	.670	.006	
	Female	26	.515	.007	
Level of education	Higher	21	.586	.005	
	Below higher	20	.469	.037	

6.10 Do the patterns of speechreading performance on the TAS core subtests differ as a function of hearing status?

As Figure 6.20 illustrates, relative performance on the three TAS core subtests was similar across the groups. For each, performance on the single words was significantly higher than on the sentences, which was significantly higher than on the stories.

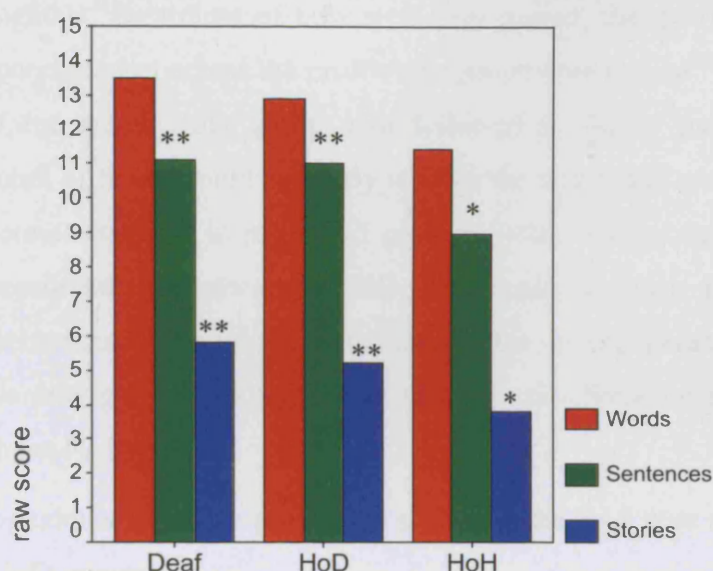


Figure 6.20: The deaf, HoH and HoD groups' performance on the individual TAS core subtests (** $p < .001$, * $p < .01$)

To investigate the patterns of performance further, the profile of subtest scores was analysed for each participant. Their profiles fell into six categories:






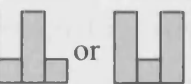
1.		Good speechreaders, scoring 10+ on every subtest
2.		Speechreaders with a 'flat' profile, whose scores on each subtest fell within 5 points
3.		Speechreaders with the expected profile: words > sentences > stories [$(wd - sent) - (sent - story) < 3$]
4.		Speechreaders scoring similarly on the words & sentences, but less well on the stories [$(wd - sent) < (sent - story)$]
5.		Speechreaders scoring similarly poorly on the sentences & stories, but better on the words [$(wd - sent) > (sent - story)$]
6.		Speechreaders with unusual profiles, not fitting into the categories above

It can be seen from Table 6.20 that 17% of the deaf speechreaders scored 10 or more on each subtest, while none of the hearing speechreaders scored that well. When the first 2 categories were collapsed, however, so that all of those with 'flat' profiles

were grouped together, regardless of how well they scored, the distributions of the deaf and HoH speechreaders across the profile categories were similar²⁶.

The profiles of the small HoD group also followed a similar pattern, although comparatively more of them scored similarly well on the words and sentences (profile 4), and none were categorised in profiles 5 or 6. In other words, none of the HoD participants' speechreading performance fell dramatically as soon as words were combined into sentences, and some segmentation of the speech stream was required (profile 5). This may partially explain their superior speechreading performance in comparison with the HoH group.

Table 6.20: Crosstabulation of the profiles of scores on the TAS core subtests for the deaf, HoH and HoD groups

	1. Good	2. Flat	3. Expected	4. Stories ↓	5. Words ↑	6. Odd
						
Deaf	7 (17%)	0	7 (17%)	23 (56%)	4 (10%)	0
HoH	0	2 (5%)	12 (29%)	20 (49%)	5 (12%)	2 (5%)
HoD	0	2 (20%)	1 (10%)	7 (70%)	0	0

The deaf and hearing participants did not, then, differ markedly in the pattern of their TAS core subtest scores as anticipated. Differences did become apparent, however, when their patterns of responses and errors within the subtests were considered.

6.10.i Single words

Within the single words subtest, 33% of the items were spondees; these were slightly easier than the monosyllabic items (see section 5.9.i). More participants responded correctly to the spondees than the monosyllables in both the deaf and HoH groups (see Figure 6.21). However, this difference reached significance only for the deaf group (deaf: $U=9.0$, $p<.05$; HoH: $U=17.5$, $p=.371$, NS).

²⁶ It was not possible to use chi-square to analyse these distributions because more than 20% (60%) of the cells would have had an expected count of less than 5.

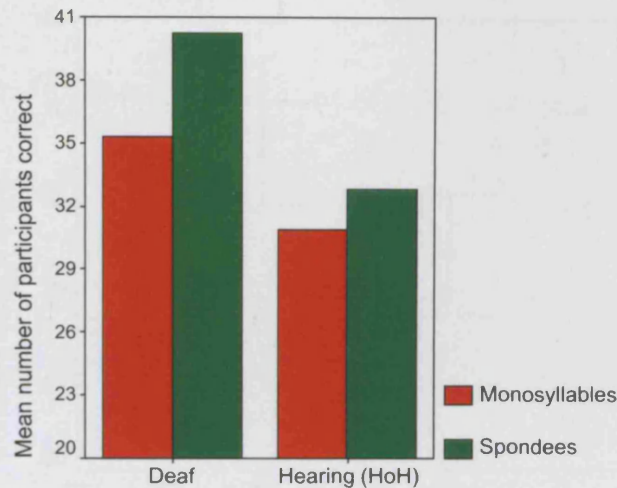


Figure 6.21: Bar chart illustrating the number of deaf and hearing (HoH) participants who responded correctly to the monosyllabic and spondaic single word TAS items

6.10.ii Sentences

For each sentence item, two to four of the five distracter pictures depicted an element of the target sentence, for example the distracters for 'The girl plays with a ball.' included two pictures that featured a ball (see section 5.9.ii for further description of this aspect of the sentence items). 53% of the distracters across the sentence subtest were 'linked' in this way to the target sentence. These distracters were chosen in 73.9% of the hearing participants' errors, and 85.3% of the deaf participants'. For both groups, this was significantly more than would be expected by chance (hearing: $t(40)=6.15$, $p<.001$; deaf²⁷: $t(39)=11.39$, $p<.001$), however the difference between the groups was also significant ($t(79)=2.59$, $p<.02$). A greater proportion of the deaf participants' errors were linked to the target sentence than those of the hearing participants (see Figure 6.22). This may indicate that a greater proportion of the deaf participants' responses were based on partial decoding of the sentence. The significantly higher number of responses to 'linked' distracters may be the result of participants understanding isolated words (such as 'ball' from the example given above), and responding based on that, whereas responses to distracter pictures that did not depict anything from the target sentence are likely to have been guesses.

²⁷ One deaf participant did not make any errors on the sentences subtest.

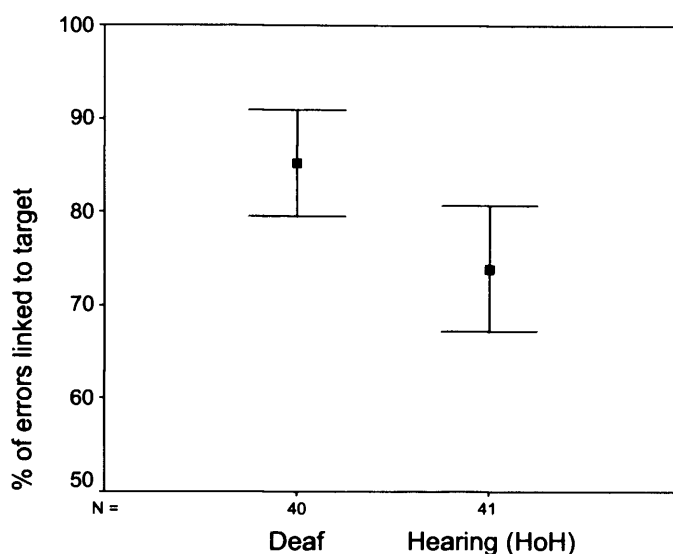


Figure 6.22: The percentage of ‘linked’ errors on the TAS sentence subtest for the deaf and hearing (HoH) participants (‘linked’ errors are those where the distracter chosen had an element in common with the target sentence; error bars show 95% confidence interval)

6.10.iii The Talkers

Participants across the groups responded correctly to significantly more of the items spoken by the female talker than to those spoken by the male talker (see section 5.9.iv). There was, however, no significant difference between the hearing participants’ responses to the items spoken by the male and female talkers: there was less than 1% difference (see Table 6.21; $z=-0.19$, $p=.850$). In contrast, 12.15% more deaf participants responded correctly to the items spoken by the female than the male talker; this difference was highly significant (see Table 6.21; $z=-4.65$, $p<.001$), and is illustrated in Figure 6.23.

Table 6.21: Deaf and hearing participants’ performances on the TAS core test items spoken by the male and female talkers

	Talker	Number of items	Min. %	Max. %	Mean %	S.D.
Deaf group (N=41)	Male	25	44	80	62.24	10.32
	Female	20	45	100	74.39	15.21
HoH group (N=41)	Male	25	28	68	54.24	9.64
	Female	20	30	95	54.63	16.06

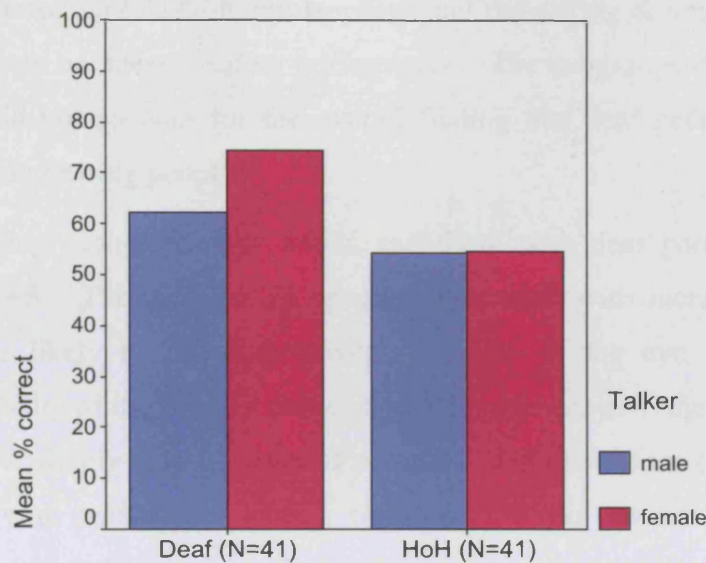


Figure 6.23: The percentage of correct responses to the TAS core subtests by the HoH and Deaf participants as a function of talker

6.17 Summary & Discussion

6.11.i Do the speechreading abilities of deaf and hearing adults differ?

Yes: adults who were born profoundly deaf performed better than hearing adults on the Test of Adult Speechreading (TAS), a speechreading test that was designed to be equitable for deaf and hearing people, and that makes no demands on the testee's literacy or speech abilities. This finding corroborates and extends the findings of Bernstein and colleagues (e.g. Bernstein et al. 2000; Demorest & Bernstein 1997), that carefully selected oral deaf college students speechread better than hearing participants. The deaf participants in this study were not selected on the basis of their educational or language experiences and preferences. In fact the majority (70.73%) identified BSL as their preferred language.

6.11.ii Are there subgroups of deaf or hearing participants with superior speechreading abilities?

Within the deaf group, superior speechreading performance on the TAS was shown by those who:

- chose to wear hearing aids
- used some English (spoken or SSE) in their daily lives
- grew up with spoken English being used in the home
- attended a selective oral grammar school
- were more risk-taking and impulsive

Only hearing aid use, childhood home language and risk-taking & impulsiveness had independent effects on speechreading performance. The subgroups of superior deaf speechreaders did not account for the overall finding that deaf people were better speechreaders than hearing people.

Within the hearing group, younger adults and those with deaf parents performed better on the TAS. The decrease in speechreading skill with increasing age was expected and is likely to reflect presbyopic changes in the eye. The superior speechreading ability of the hearing participants with deaf parents (the HoD group) is unlikely to reflect simply their heightened awareness and knowledge of language and communication with deaf people, since a similar ability was not seen in late-signing hearing participants who worked facilitating communication between deaf and hearing people (see Study 6A). Rather, experience of communicating with deaf people throughout childhood and during the development of language is hypothesised to result in superior speechreading skills.

These findings with regard to parental hearing status and age were not seen in the deaf group. The null finding for the former was not unexpected, and is in line with previous findings of no significant difference between these groups (e.g. Meadow 1968; Quigley & Frisina 1961). Deaf participants with deaf and hearing parents respectively each have relative speechreading advantages: those with hearing parents (the DoH group) will have grown up surrounded by spoken language in the home, and may have had a stronger motivation to communicate through speech. The deaf participants with deaf parents (the DoD group), on the other hand, are likely to have been diagnosed earlier, to have benefited from better communication strategies in their early childhood, and to have developed better visual attention skills. These respective advantages for speechreading may have resulted in no difference in the speechreading ability of the two groups. A concern regarding the comparison of these groups was that some of the DoH participants, whose deafness is less likely to have a genetic cause, might have mild additional disabilities not identified during screening (see section 2.4). As expected, fewer DoHs than DoDs reported a genetic cause of deafness (100% of the DoDs and 35% of the DoHs). There was no evidence, however, of any non-identified additional disabilities in the DoH group. In the deaf group as a whole, those who reported that their deafness was genetic did not perform better on the TAS than the other participants.

The null finding with regards to age suggests that speechreading may be less susceptible to deterioration with increasing age in people who are deaf. This may be because in this group speechreading is a consciously used and practiced skill. It should be noted, however, that the oldest deaf participant was aged 60;1. Decreased speechreading performance due to presbyopic changes in the eye would be expected for older speechreaders.

There was also a null finding with regards to the predicted relationship between speechreading performance and age at exposure to BSL. In addition, no significant difference in speechreading ability was found as a function of the communication mode used in school with the deaf participants (speech or total communication). There is no evidence of any impact of BSL experience or use on speechreading ability in this study. What does appear to be important is experience (and use) of spoken language. This concurs with Bernstein and colleagues' (1998a) findings of a significant relationship between speechreading performance and the use of speech for communication, but no relationship between speechreading and the use of ASL. Early exposure to BSL and the use of spoken language in childhood are not mutually exclusive. There were participants who experienced BSL from birth or early childhood and grew up using speech or a mixture of signed and spoken language at home. However, these participants were in the minority. In most cases, early exposure to BSL was associated with use of BSL in the home, and those who used spoken language experienced BSL later (the mean age at exposure to BSL for participants who were not exposed to it before 5 years of age was 13.88 years). This is illustrated in Figure 6.24. Earlier findings of a relationship between speechreading performance and age at exposure to signed language (Parasnis 1983) may therefore have reflected experience of *spoken* language rather than a true relationship between signed language and speechreading.

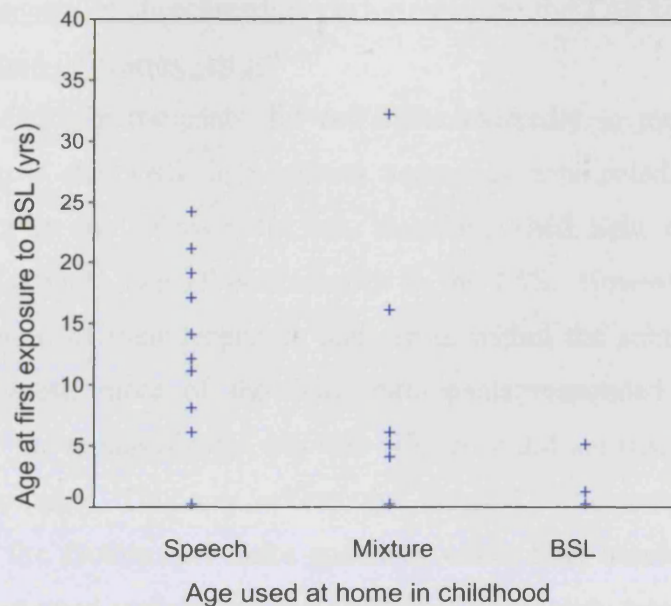


Figure 6.24: Age at first exposure to BSL as a function of the language used at home in childhood

6.11.iii Are deaf adults better than hearing adults at rating their speechreading ability?

Yes, as expected the deaf group were more accurate at rating their speechreading ability than the hearing group. This corroborates Demorest and Bernstein's (1997) finding that deaf people were more accurate judges of their own speechreading performance on a subjective confidence rating scale than hearing people. It is also consistent with the interpretation above regarding the lack of significant deterioration in speechreading skill with increasing age in the deaf group. The overt awareness that deaf people have of their speechreading abilities may enable them to capitalise on their strengths and compensate for their weaknesses in speechreading, and may therefore be one factor that enables them to speechread better than their hearing peers. It is notable that, although there was no difference in speechreading performance as a function of parental hearing status for the deaf group, there was a difference in their accuracy of self-rating. The correlation between self-rating and performance was significant only for those with hearing parents, that is for those who grew up surrounded by spoken language in the home and who may have had a stronger early motivation to communicate through speech and speechreading.

6.11.iv Do the patterns of speechreading performance on the TAS core subtests differ as a function of hearing status?

The deaf and hearing participants did not differ markedly in the pattern of their performance across the TAS core subtest scores as anticipated. Their relative performances across the subtests did not, therefore, shed light on the difference between the two groups' over-all performance on the TAS. However, the groups did differ in the pattern of their responses and errors within the subtests. Within the single words subtest, more of the deaf participants responded correctly to the spondees than to the monosyllables, but this difference did not reach significance for the hearing participants. This may indicate that the deaf participants were better able to make use of the factors that make spondees easier than monosyllables. These include the two stressed vowels, and the additional articulatory movement associated with their two syllables. In addition, more deaf participants responded correctly to the items spoken by the female than the male talker, although no difference was seen as a function of talker for the hearing group. It is possible that deaf speechreaders are more sensitive to differences in talker than hearing speechreaders.

A further difference between the groups was found in the sentence subtest errors: a greater proportion of the deaf participants' errors were 'linked' to the target sentence (the chosen distracter depicted aspects of the target sentence) than those of the hearing participants. This may indicate that a greater proportion of the deaf participants' responses were based on partial decoding of the sentence. The significantly higher number of responses to linked distracters may be the result of participants understanding isolated words (such as 'ball' from the example given above), and responding based on that, whereas responses to distracter pictures that did not depict anything from the target sentence are likely to have been guesses.

To further elucidate the different speechreading abilities of deaf and hearing adults, their performance on two additional speechreading tasks, assessing their ability to discriminate between minimal pairs, and to identify the focus of a speechread sentence respectively, will be considered in Chapter 7.

Chapter 7

FURTHER ASSESSMENT OF SPEECHREADING:

MINIMAL PAIRS AND FOCUS

7.1 Introduction

Chapter 6 has shown that the deaf participants outperformed the hearing participants on the TAS core subtests. However, the two groups did not differ in their profiles of scores on the core subtests. To investigate their speechreading skills further, two additional speechreading tasks were used. The development of these tasks, the groups' performance on them, and the relationships between the speechreading measures will be considered in this chapter.

The additional subtests described here were developed in parallel with the further development of the TAS core subtests (described in Chapter 5, Section A). Additional subtests were required to assess speechreading at the phonological level (the minimal pairs subtest), and to assess the visual perception of an aspect of prosody (the focus subtests). The objectives and development of these additional subtests will be discussed in turn below.

7.2 Why develop additional subtests?

7.2.i Minimal pairs

The relative importance of bottom-up and top-down processing in speechreading is unclear. One argument is that good speechreaders must depend on top-down processes, non-linguistic context, and strategies such as guessing to decode a speechread message (see e.g. Rönnberg et al. 1998). Support for the top-down argument is provided by the relatively small proportion of the segmental speech signal that can be perceived visually (see section 3.3). Several contrastive phonemes often form one visemic category (e.g. /m/, /p/, and /b/), and many of the phonemes articulated further back in the oral cavity cannot be seen at all (e.g. /h/, /g/). On the other hand, it has been argued that high levels of visual phonetic perception *are* possible (see section 3.3), and that the most successful speechreaders use bottom-up processing (see e.g. Bernstein et al. 2000).

The minimal pairs subtest was developed to investigate this issue further: it was designed to assess the identification of phonemes in meaningful contexts. At the simplest level, if speechreading is driven by bottom-up processing, then testees who score well on the TAS core subtests should also score well on the minimal pair subtest. If it is not, and better speechreaders actually use top-down processes, then no relationship would be expected between them.

Manipulations within the minimal pairs subtest will enable individuals' performances on visemically similar and dissimilar words, and on pairs which differ word initially, word medially and word finally to be investigated. Performance on the visemically similar words (e.g. 'pat' and 'mat') is particularly interesting given the disagreements in the literature about the degree to which words can be identified visually (see section 3.3). On one hand, it has been claimed speechreaders can only perceive visemes (Fisher 1968; Massaro 1987; Massaro 1998), in which case performance on the visemically similar pairs would be at chance. However, Kaczmarek (1990) proposed that features characteristic of individual sounds could be distinguished visually, and Bernstein and colleagues (2000) suggest that skilled speechreaders can perceive 'sub-visemic' information.

Including items that differed word initially, medially (the vowel), and finally was considered important for a number of reasons:

- The onsets of words are proposed to be especially important in segmenting speech (Sanders & Neville 2003a; see section 3.2.ii). Performance on the word initial minimal pair items may therefore be expected to correlate with performance on the sentence and, particularly, the story level subtests, since these require the speech stream to be segmented.
- As well as giving cues for the identification words, vowel intensity and duration provides important information about the stress patterns of seen speech (Risberg & Lubker 1978). Head and facial feature movements may also provide prosodic information. If speechreaders use the changes in the vowel duration to identify stressed words, performance on the focus subtest would be expected to correlate with the ability to discriminate between vowels (which is tested with the word medial items). If performance on the word medial minimal pairs and focus are not related, but testees are able to perform the focus task, that may indicate that they are using facial expression and/or head movement cues to identify focus instead.

- The word positions in this subtest are partially mirrored in the phonological awareness tasks which will be discussed in Chapter 9 (see section 9.2.ii). The ‘phoneme’ phonological awareness task requires participants to decide whether the initial phonemes of two pictured words sound the same. The ‘onset-vowel’ task requires a decision about the initial phoneme and the vowel, and the ‘rhyme’ task, the vowel and final phoneme. If speechreading was instrumental in the development of the deaf participants’ phonological representations (see sections 2.21 and 3.8), then performance on the phonological awareness tasks may be expected to correlate with performance on the minimal pairs items that focus on the corresponding part of the word. Performance on the phoneme task may thus be expected to correlate with performance on the word initial items; performance on the onset-vowel task with performance on the word medial and word initial items; and the rhyme task with the word final and word medial items. This question will be investigated in Chapter 9.

7.2.ii Focus

Sentence prosody solves syntactic ambiguities, and identifies syntactic boundaries (Schepman & Rodway, 2000). The ‘metrical segmentation strategy’ (see section 3.2.iii) suggests that recognition of stress is important in segmenting an English speech stream: English listeners use knowledge of strong and weak syllable stress patterns to make an initial assessment of the location of the potential onsets of words in fluent speech (Cutler & Carter 1987; Cutler & Norris 1988). English listeners insert word boundaries before stressed syllables (Cutler & Butterfield 1992; Cutler & Norris 1988; McQueen et al. 1994; Vroomen & de Gelder 1995). Prosodic stress may be an especially important cue for speechreaders, since the stressed portions of the signal may be easier to perceive (because the vowel is not reduced in stressed syllables). The focus subtest was developed to begin to explore the extent to which prosodic information can be perceived visually, and the importance of this for speechreading.

7.3 **Development of the minimal pair subtest items**

7.3.i Test format

The minimal pairs subtest was developed to have a similar format to the core subtests. The same two talkers (one male, one female) each presented half of the items; they were recorded audiovisually with a head and shoulders view, and looked up to attract

the testee's attention before speaking the item. Also similarly, the response mode selected was multiple-choice picture pointing. However, for this subtest the choice is between only two pictures (which represent a minimal pair of words – that is, words which differ in just one phoneme, e.g. 'doll' and 'dog'), and the pictures are captioned with the words they represent. The captions were provided to remove any ambiguity about the words represented so that the speechreading task was to discriminate between phonemes in meaningful contexts rather than to identify the words (which is assessed in the word subtest, see Chapters 4 and 5, and Appendix D). The combination of the picture and single word should not have disadvantaged poorer readers, but caution will still need to be applied in investigating any relationship between this subtest and reading. In addition, the items in this subtest were presented in a random order to each participant so that the effect of practice on an individual item varied. Half of the targets were presented on the right, and half on the left.

7.3.ii Test items

A pool of 418 highly imageable CVC minimal pairs was created, contrasting word initial (WI) and word final phonemes (WF) for each possible pair of the following consonants: /p, b, t, d, k, g, m, n, ŋ, f, v, θ, ð, s, z, ʃ, h, tʃ, dʒ, w, l, r, j/. Word medial (WM) pairs contrasted the vowel monophthongs /a, e, ɜ, ɪ, i, ɒ, ɔ, ʌ, ʊ, u/, and diphthongs /aɪ, aʊ, eɪ, əʊ, ɔɪ/ (those ending in /ə/ were excluded for simplicity).

From this pool, pairs were excluded if

- the familiarity value of either word was less than 400
- the difference between the familiarity values of the two words was greater than 120
- the difference between the frequency values of the two words was greater than 100 (the values of Kucèra & Francis 1967 were used)
- either word could not be easily illustrated using pictures from the ArtToday website (this excluded all incidences of the voiced fricative /ð/).

Words with the vowel /ʌ/ (as in 'cut' in an RP accent) were also excluded because some Northern English accents do not have a contrast between [ʊ] as in 'look' and [ʌ] as in 'luck'.

Sixty items (twenty word initial, twenty word final and twenty word medial) were selected from the remaining pairs, and one of each pair was designated the target

word, such that as far as possible there was an even spread of words across the phonemes in each word position (see Table 7.1).

Table 7.1: The frequencies of phonemes in target & distracter minimal pair words

Word Final			Word Initial			Word Medial		
	targets	distracters		targets	distracters		targets	distracters
p	1	2	p	1	1	a	1	2
b	1	1	b	1	1	ar	1	1
t	1	2	t	1	1	e	2	1
d	1	1	d	1	1	er	1	2
k	1	2	k	1	1	i	2	2
g	2	1	g	1	1	ee	2	1
m	1	0	m	1	1	o	2	2
n	2	2	n	1	1	or	1	2
ng	1	1	f	1	1	u	1	1
f	1	1	v	1	1	oo	2	1
v	1	0	th	1	0	ie	1	1
th	1	1	s	1	2	ow	1	2
s	1	1	z	1	1	ay	1	0
z	1	1	sh	1	1	oe	1	2
sh	1	1	ch	1	1	oy	1	0
ch	1	1	j	1	1			
j	0	1	l	1	1			
l	2	1	w	1	1			
			r	1	1			
			h	1	0			
			y	0	1			

The mean difference between the frequencies of the words in a pair was 27.38, and the maximum was 96. There was no significant difference between the frequencies of the target and distracter words overall ($t(59) = 1.03$, $p = .308$; see Table 7.2).

Table 7.2: Frequency values for the included target and distracter minimal pair words

	N	Minimum	Maximum	Mean	SD
Targets	60	1	212	43.17	46.38
Distracters	60	1	233	38.08	53.19

Familiarity data was not available for all words, but for the 42 pairs where it was for both words, the mean difference between the pairs was 43.40, and the maximum difference 113. There was no significant difference between the familiarity of the target and distracter words overall ($t(41) = 0.364$, $p = .718$; see Table 7.3).

Table 7.3: Familiarity values for the included target and distracter minimal pair words

	N	Minimum	Maximum	Mean	SD
Targets	49	443	610	545.49	40.36
Distracters	51	454	618	543.65	42.91

Place and manner of articulation were not controlled beyond an awareness of these factors during pair selection. The task was designed to include a mixture of difficult and easier pairs, and so included some in which the distinguishing phonemes have the same place of articulation (and therefore differ only in manner, which is difficult to perceive visually), and some in which the place of articulation differs. Table 7.4 shows the percentages of such items included. The pairs in which the distinguishing phonemes were categorised as a single viseme by Walden and colleagues (1977; see section 3.3.i, pg. 87) were also identified. This classification of visemes was chosen because it is the most frequently referred to in the literature (see e.g. Bernstein et al. 2000; Summerfield 1987).

Table 7.4: Table showing the number and percentage of minimal pair items with the same manner or place of articulation, and the percentage of those belonging to the same visemic category

	WF (N=20)		WI (N=20)	
	N	%	N	%
Same manner	6	30%	5	25%
Same place	4	20%	7	35%
Similar place (alveolar – post-alveolar)	1	5%	3	15%
Same viseme	4	20%	4	20%

7.4 Development of the focus subtest items

7.4.i Test format

The focus subtest was designed, as far as possible, to have a similar format to the other TAS subtests. Again, the items were spoken by the same two talkers, following the same filming procedure, with laptop-based picture-pointing responses. Each response screen was seen for familiarisation before the sentence was spoken. On the response screen the sentence to be speechread was written, with five of the words highlighted and pictured. An example (for the practice item) is shown in Figure 7.1 (see also Appendix D).

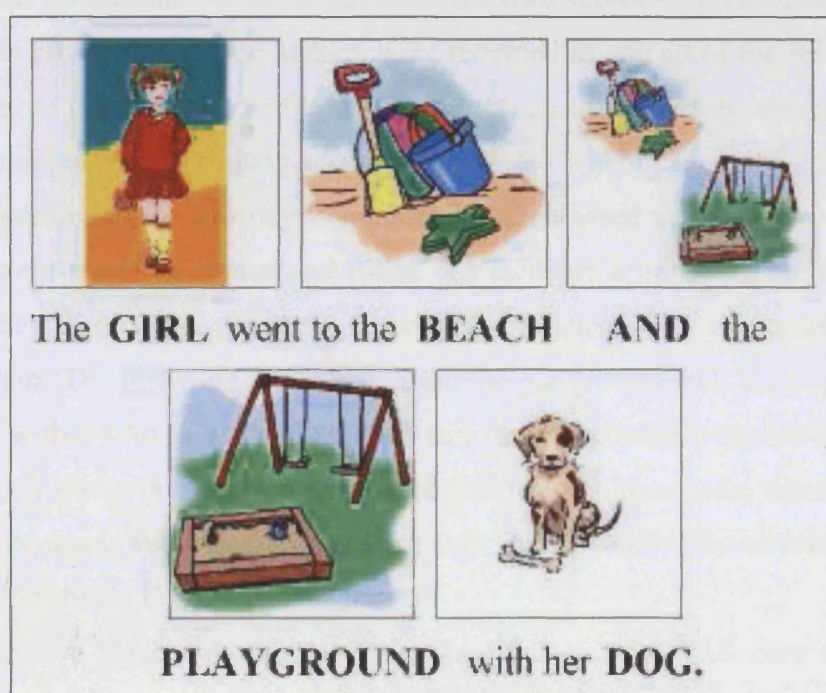


Figure 7.1: A familiarisation / response screen for the focus subtest

The response screen, with its pictures, was presented again after the speechread item had been seen. The testee was asked to click on the picture of the word that they thought had been stressed or emphasised.

7.4.ii Test items

Fifteen sentences (9 to 13 words in length), with simple vocabulary, were written so that each had five words that could meaningfully carry the focal stress. Ten were selected as test items through discussion with colleagues, and 1 selected as a practice item. Several trials of this subtest were run with adult hearing volunteers to rehearse the presentation of the test items, and to determine whether the task would be possible for speechreaders. The results varied according to the recording used, and

only a small number of volunteers saw each recording, but some reported finding it reasonably easy, while others reported finding the same recording difficult. This was encouraging because it suggested that a properly recorded set of test items might discriminate between testees. The request of one volunteer for more practice was also taken into account, and the decision made to record five examples of the practice item: one with each possible target word stressed.

7.5 Filming & Digitisation

The 120 CVC minimal pair words (targets and distracters), and 11 focus sentences were filmed on the same occasion as the TAS core subtests, in the same conditions (detailed in section 5.4). Both talkers were recorded saying all of the items. At least two tokens of each item were filmed so that the clearest could be selected, and any mistakes missed during filming could be discarded without the need for re-filming. The presentation of the prosody items had been rehearsed previously to identify the appropriate levels of intonation and stress. To facilitate achieving these levels during filming, the talker spoke the items in response to questions. For example, for the practice item ‘The girl went to the beach and the playground with her dog’, the talker was cued with “*Who* went to the beach and the playground with her dog?”. Two hearing adult observers were present while the prosody items were filmed, to ensure that each item was produced clearly such that, audiovisually, the stressed word was easily identifiable but not over-exaggerated.

The deaf native signer who signed the instructions for the TAS core subtests was filmed signing the instructions for these additional subtests in BSL on the same occasion, and in the same conditions.

The stimuli and instructions were then transferred into Adobe Premiere, and the resultant AVI files edited, selected, cropped, and converted to MPEGs as the items for the TAS core subtests had been (see section 5.4). The new subtests were built into the Test of Adult Speechreading program (written by Dr Mike Coleman), so that there was a selection of tasks (TAS, minimal pairs, focus). These new subtests follow the same format as the TAS (described in section 5.4), except that

- The talker familiarisation (where each said the days of the week) was not repeated for each subtest: it was anticipated that the TAS core subtests would always be presented to testees before the additional subtests.
- The 60 minimal pair test items were presented in a random order.

- The familiarity / response grid for the focus subtest was presented both before and after the item to be speechread.
- The feedback for the additional subtests was not signed or written: a tick or cross, with highlighting of the correct picture suffices.

7.6 Piloting of the additional subtests

7.6.i Minimal Pairs

The minimal pairs subtest was piloted on 14 hearing (6 male) and 13 deaf (4 male) adults. Table 7.5 shows the ranges and means of their scores:

Table 7.5: Descriptive statistics showing deaf and hearing participants' performance on the pilot of the minimal pairs subtest (max score: 60)

	N	Min	Max	Mean	S.D.
Deaf	13	50	57	53.92	2.14
Hearing	14	43	52	48.71	2.81

As can be seen from Table 7.5, the scores were all surprisingly high. Item analysis showed that a number of the test items were not contributing to the overall test score (the scores on these items were at ceiling). The non-discriminatory items were spread across the contrastive word positions (word final, word initial and word medial), so the decision was made to reduce the number of items by half, discarding the items with scores at ceiling, but maintaining the balance of items across the word positions. The items with the highest scores were therefore discarded, and some of the target and distracter positions were swapped so that 5 targets appeared on the left, and 5 on the right for each of the three word position categories. The distribution of items between talkers was also maintained (half spoken by the male and half by the female talker). None of the visemically similar items (that is, items in which the discriminatory phoneme of the target and distracter fall into the same visemic category using Walden and colleagues' (1977) visemic groups) were discarded. Eight of these items therefore remain: four WI and four WF. Table 7.6 shows the frequency and familiarity data for the selected thirty items; there was no significant difference between the target and distracter words in either the frequency ($t(29)=.548$, NS), or the familiarity ($t(21)=.044$, NS) values.

Table 7.6: The mean and standard deviations of the familiarity and Kucèra-Francis frequency values for the selected targets and distracters in the minimal pairs test

		N	Mean	SD
Frequency	Targets	30	39.83	38.99
	Distracters	30	35.50	45.93
Familiarity	Targets	22	542.0	39.43
	Distracters	22	541.5	48.22

The frequency and familiarity differences were also explored between the targets categorised by word position. Table 7.7 shows the means and standard deviations, and again there were no significant differences, but it is noticeable that the word medial words had a higher mean frequency than the other positions, and the word initial words had a lower familiarity.

Table 7.7: The familiarity and frequency values of the minimal pair targets by word position

	Position	N	Mean	SD
Frequency	WF	10	30.10	23.10
	WI	10	27.30	23.37
	WM	10	62.10	54.66
Familiarity	WF	8	550.13	9.73
	WI	9	518.33	13.80
	WM	9	552.33	42.75

Following these changes, the reduced minimal pairs subtest was used in the main test battery. Performance on the test was monitored, however, and after sixteen deaf participants and seventeen hearing participants had been assessed on it, their mean scores for each item were compared with the mean scores (on the same items) of the participants who had been assessed on all sixty items. For both deaf and hearing participants, there was a significant correlation between the scores (deaf: $r=.866$, $p<.001$; hearing: $r=.819$, $p<.001$), and no significant difference between them (deaf: $t(29)=.782$, NS; hearing: $t(29)=.035$, NS). The test items, therefore, appeared to be functioning as they had when as part of the longer test. The task was now quick, easy to administer, and discriminatory. The test items and an example of a response screen are shown in Appendix D.

7.6.ii Focus

The focus subtest was piloted on 30 hearing (12 male) and 26 deaf adults (8 male). Table 7.8 shows the range and means of their scores.

Table 7.8: Descriptive statistics showing deaf and hearing participants' performance on the pilot of the focus subtest (max score: 10).

	N	Min	Max	Mean	S.D.
Deaf	26	3	10	7.23	1.82
Hearing	30	6	10	8.5	1.04

This subtest only includes ten items, and many of the hearing scores were at or near ceiling. However, there was an acceptable range of scores, particularly for the deaf participants: the task did appear to discriminate between participants. Item analysis (see section 7.7.ii) showed a spread of errors over the distracters. This indicated that single distracters did not appear stressed, and there was no tendency to select the final word, which carries an idiosyncratic stress pattern because it marks the end of the sentence. The focus test was therefore not changed, except for a reduction in the number of practice trials from five to two (the extra trials had in practice proved tedious for testees, rather than reassuring).

7.7 **Item analyses**

7.7.i Minimal pairs

The number of participants scoring correctly on each of the minimal pair items is illustrated in Figure 7.2. It can be seen that there was enormous variability in the relative difficulty of items in each of the word positions. The 'visemic' items are indicated by stars, and performance tends to be poor on these items. Performance is at chance for items 15 and 20 (both WI), and below chance for four additional items, one word-final (item 3), one word-initial (16), and two word-medial (23 & 29).

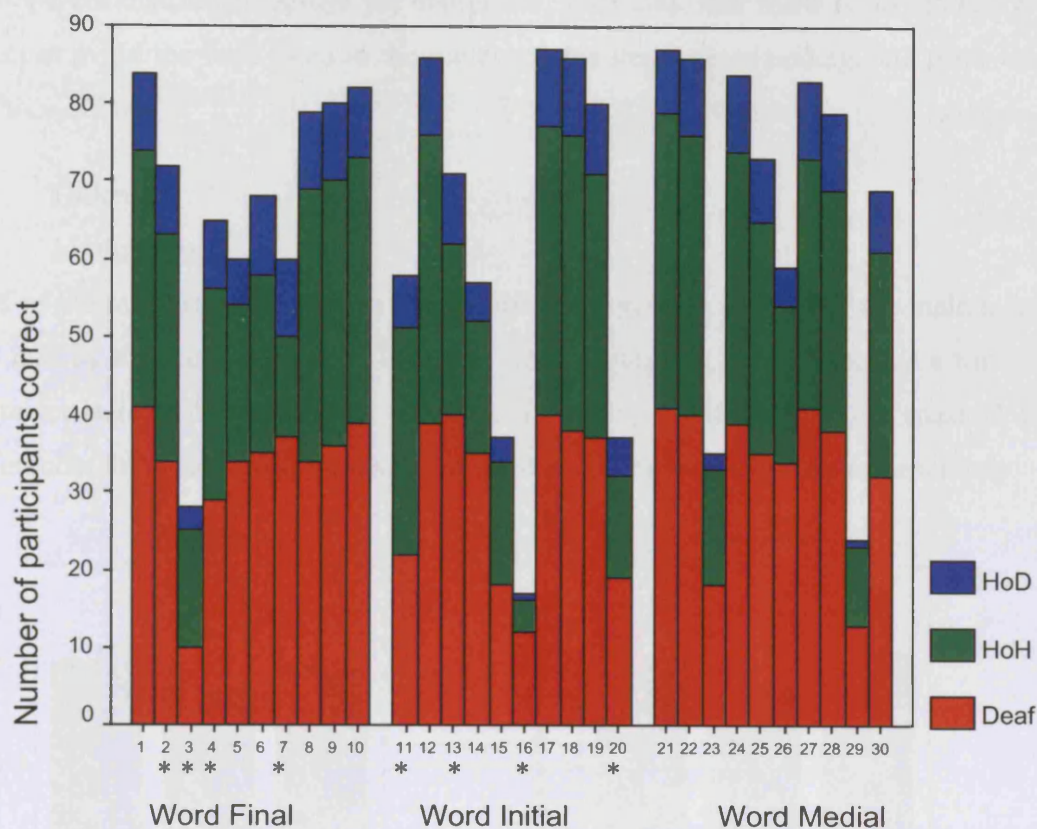


Figure 7.2: Bar chart illustrating item analysis of the minimal pairs task (* indicates visemically similar items)

7.7.ii Focus

The participants' error patterns were analysed by picture position, and the frequencies of responses can be seen in Table 7.9.

Table 7.9: Item error analysis for the focus task (; A to E represent grid positions of response choices; **red** indicates correct response)

	A	B	C	D	E
1	3	15	41	2	27
2	3	3	1	2	79
3	27	53	6	1	1
4	4	2	21	2	59
5	2	0	2	84	0
6	9	70	3	2	4
7	5	2	73	5	3
8	4	6	5	71	2
9	72	4	7	1	4
10	1	0	1	82	4

Errors were distributed across the distracters' positions, and there is no tendency to select or avoid the final word in the sentence. No item was at ceiling, and there were no floor effects.

7.8 Talkers

7.8.i Minimal pairs

Half of the minimal pair items in each word position were spoken by the male talker, and half by the female talker. There was no difference in performance as a function of talker across the subtest as a whole ($z=-0.86$, $p=.389$), but this masked the differences that were apparent when the word positions were considered separately.

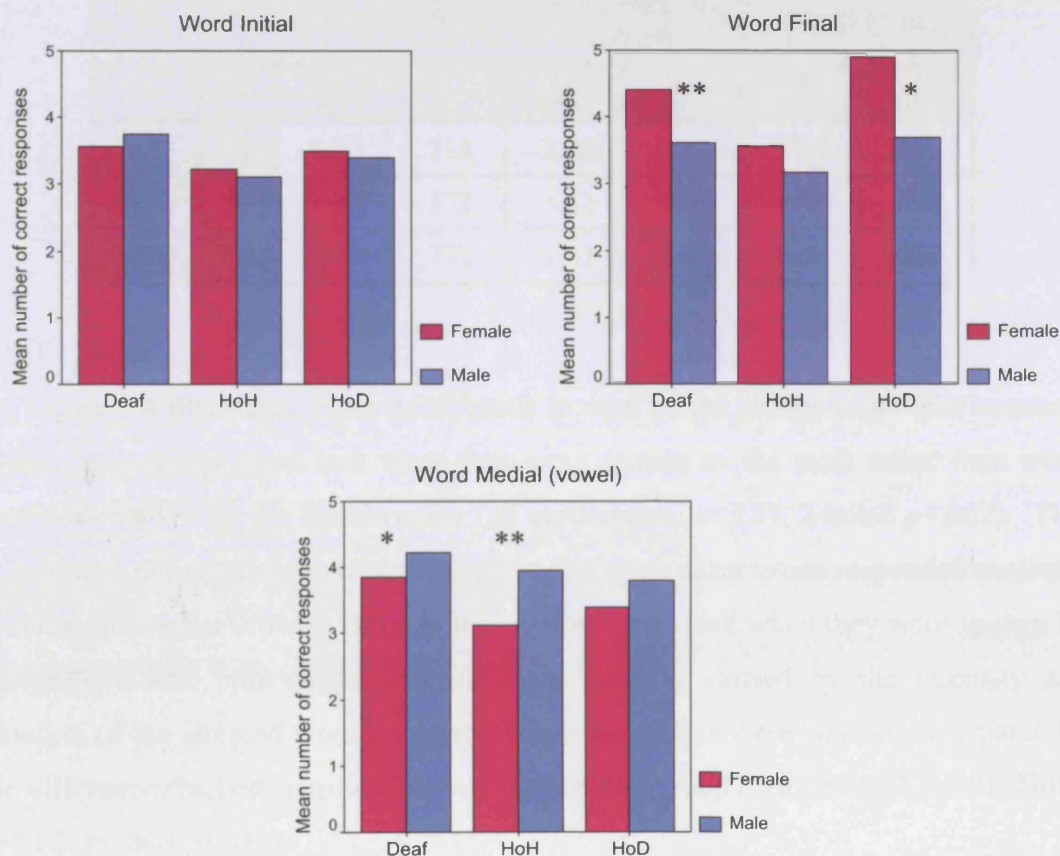


Figure 7.3: Bar charts showing the performance of the deaf, HoH and HoD groups on the word initial, word final and word medial (vowel) minimal pair items as a function of the talker (male / female) (** $p<.002$, * $p<.02$)

On the word final items, performance was higher for the female talker ($z=4.53$, $p<.001$), and on the word medial (vowel) items, performance was higher for the female talker ($z=-4.44$, $p<.001$). There was no difference as a function of talker for

the word initial items ($z=-0.35$, $p=.729$). The performance of the deaf, HoH and HoD participants on these items respectively is illustrated in Figure 7.3.

It can be seen that the difference in performance on the word final items spoken by the male and female talkers reached significance only for the deaf and HoD groups, and the difference in the word medial (vowel) items, for the deaf and HoH groups (see Table 7.10 for the Wilcoxon signed ranks statistics for these differences).

Table 7.10: Comparison of the word initial, word medial (vowel), and word final minimal pairs items as a function of the talker for the deaf, HoH and HoD groups (Wilcoxon signed ranks statistics; 2-tailed significance)

	N	Word Initial		Word Medial (vowel)		Word Final	
		Z	p	Z	p	Z	p
Deaf	41	-1.23	.218	-2.38	.017	3.87	.000
HoH	39	.893	.372	-3.41	.001	1.68	.094
HoD	10	.264	.792	-1.41	.157	2.40	.016

7.8.ii Focus

As Figure 7.4 illustrates, more participants in each of the groups responded correctly to the items in the focus task when they were spoken by the male talker than when they were spoken by the female talker (all participants: $z=3.37$, 2-tailed $p<.002$). This is, perhaps, not surprising given the finding that more participants responded correctly to the word medial (vowel) items in the minimal pairs task when they were spoken by the male talker: information that indicates focus is carried by the intensity and duration of the stressed word's vowel. When the groups were considered separately, the difference reached significance only for the deaf group (deaf: $z=2.64$, $p<.01$; HoH: $z=1.82$, $p=.068$; HoD: $z=1.13$, $p=.257$).

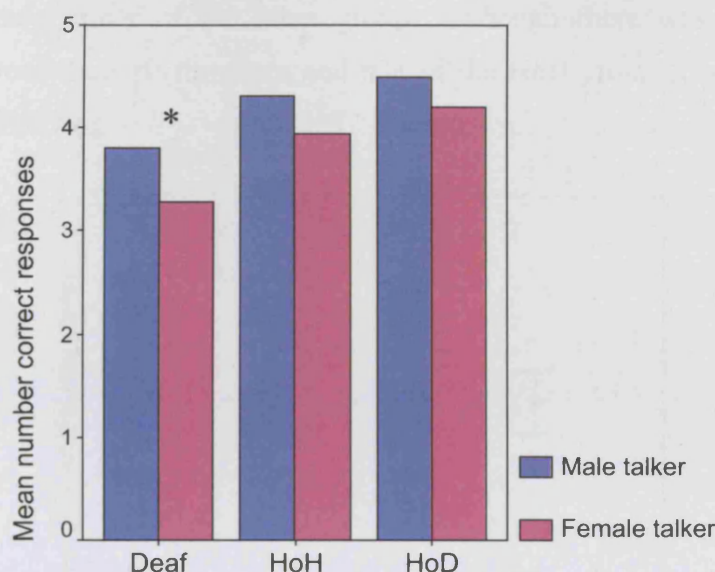


Figure 7.4: Bar chart showing the performances of the deaf, HoH and HoD groups on the focus task items as a function of the talker (male / female) (* $p < .01$)

7.9 Deaf and hearing participants' performance on the additional subtests

The hearing participants were expected to outperform the deaf participants on the minimal pairs subtest as a result of their predicted superior phonological coding and processing skills. Conversely, the deaf participants were expected to perform better than the hearing on the focus subtest, as it was anticipated that the former might be better at detecting prosodic information from facial expressions.

As Figures 7.5 and 7.6 show, the results were surprising on both counts²⁸. The deaf participants achieved a significantly higher mean score on the minimal pairs subtest ($t(78)=6.11$, 2-tailed $p < .001$; see Figure 7.5). And the hearing (HoH) group performed significantly better on the focus subtest ($U=445.0$, 2-tailed $p < .002$; see Figure 7.6). Figure 7.6 also illustrates the high scores achieved by all participants on the focus subtest: the cut off of the y-axis is at chance, and it can be seen that all groups performed well above this level: focus *can* be perceived through vision alone.

The small HoD group performed particularly well on both subtests. On the minimal pairs, they scored significantly better than the HoH group ($t(47)=2.90$, 2-tailed $p < .01$; see Figure 7.5), and there was no significant difference between their performance and that of the deaf group ($t(49)=1.13$, 2-tailed $p = .266$). On the focus subtest they

²⁸ The distributions of the minimal pairs and focus data were analysed and transformed as necessary prior to these investigations. These distribution analyses are presented in Appendix M.

scored better than either of the other groups, although there was no significant difference between their performance and that of the HoH group ($U=153.0$, 2-tailed $p=.328$; see Figure 7.6).

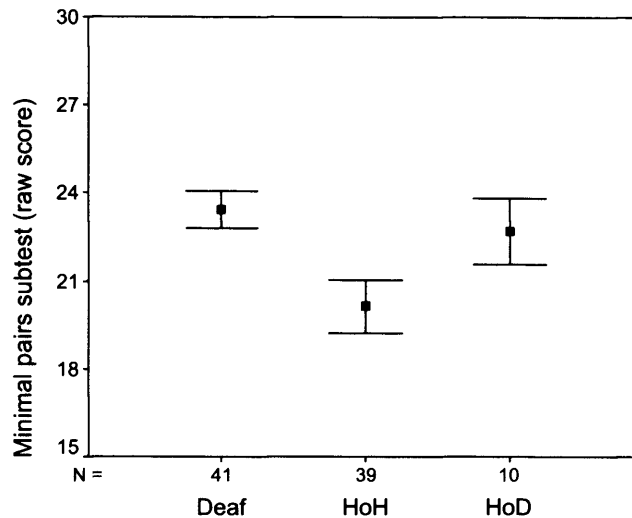


Figure 7.5: Mean raw scores on the minimal pairs subtest for the Deaf, HoH and HoD groups (error bars show a 95% confidence interval)

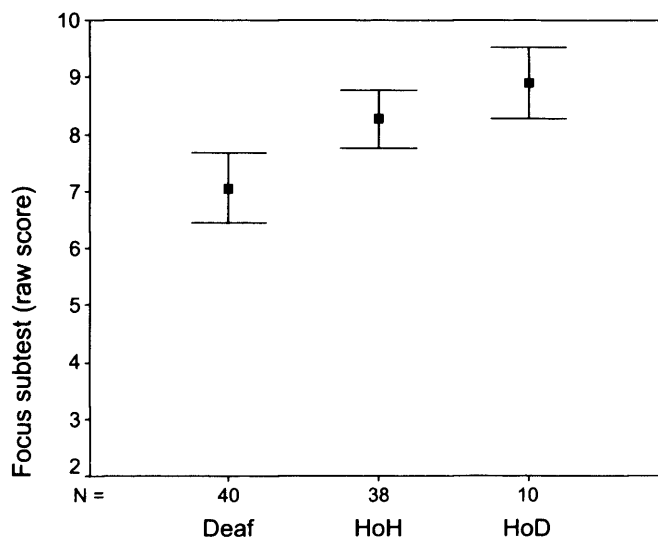


Figure 7.6: Mean raw scores on the focus subtest for the Deaf, HoH and HoD groups (error bars show a 95% confidence interval)

A comparison of the performance of the 22 matched pairs of deaf and hearing participants (see Chapter 6, pg. 173, for details) on the minimal pairs and focus subtests substantiated the surprising pattern of results. The pairs of participants were matched on age, gender, parental hearing status, level of education, and regional spoken accent, thereby reducing the variability between the groups as far as possible.

The pattern of performance on the additional subtests for the deaf and hearing groups remained unchanged with these reduced matched groups. The deaf participants significantly outperformed the hearing on the minimal pairs subtest ($U=122.5$, 2-tailed $p<.01$), and the hearing participants outperformed the deaf on the focus subtest ($U=106.0$, 2-tailed $p<.002$).

7.10 Within the minimal pairs subtest

The groups' patterns of performance within the minimal pairs subtest also differed (see Figure 7.7). The deaf and HoH groups both performed best on the word medial (WM) items, then on the word final (WF) ones, and less well on the word initial (WI) items. Both performed significantly better on the WM than on the WI items ($z=3.00$, 2-tailed $p<.005$). However, the deaf group also performed significantly better on the WF than on the WI items ($z=2.57$, 2-tailed $p<.02$), whereas this difference was not significant for the HoH group ($z=.84$, 2-tailed $p=.401$). The deaf group, then, performed comparatively better on the WF items, with respect to their performance on the other items, than the HoH group did.

The HoD group showed a different pattern of performance: they scored significantly higher on the WF items than on the others (WI: $z=2.32$, 2-tailed $p<.05$; WM: $z=2.35$, 2-tailed $p<.02$), and there was no difference between their performance on the WI and WM items ($z=.647$, 2-tailed $p=.518$, NS).

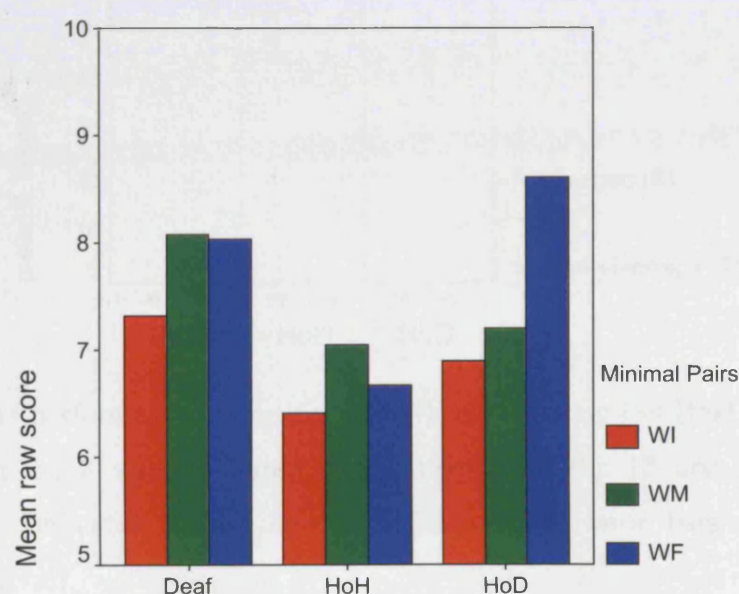


Figure 7.7: Performance of the deaf, HoH and HoD groups on the minimal pairs items broken down by word position: word initial (WI), word medial (WM) and word final (WF)

7.10.i Performance on the visemically similar test items

For four of the ten word initial and word final items respectively, the target phoneme and its distracter belonged to the same visemic category (using Walden and colleagues' 1977 nine categories, see section 3.3.i). These items were expected to be more difficult than the other items, and to be at chance if speechreaders can perceive only visemes.

As Figure 7.8 illustrates, all of the groups performed significantly better on the non-visemic minimal pair items than they did on the visemic items (deaf: $t(40)=24.92$, $p<.001$; HoH: $t(38)=21.94$, $p<.001$; HoD: $t(9)=12.04$, $p<.001$). The deaf group outperformed the HoH group on both the visemic ($t(78)=4.13$, $p<.001$) and non-visemic items ($t(78)=5.05$, $p<.001$). The HoH group performed at chance on the visemic items: there was no significant difference between their performance and the chance level of 50% ($t(38)=-.52$, $p=.606$). The deaf and HoD groups, however, both performed significantly better than chance on these items (deaf: $t(40)=5.81$, $p<.001$; HoD: $t(9)=4.33$, $p<.005$).

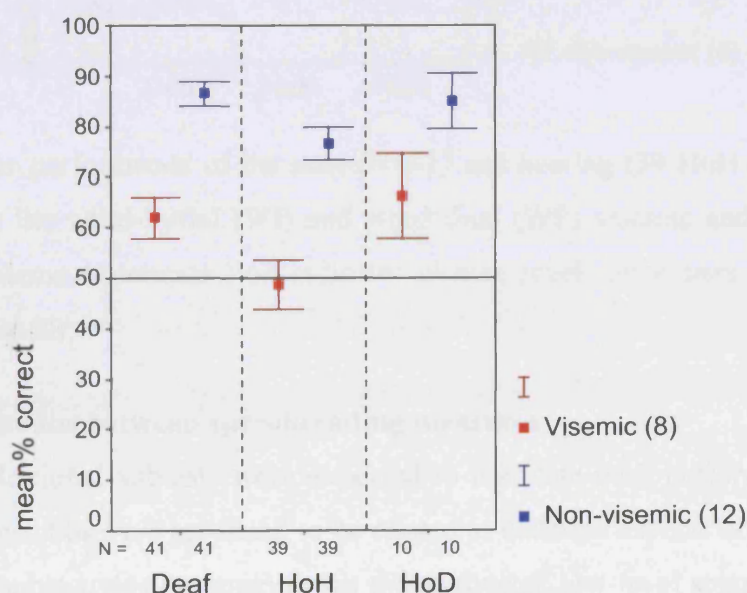


Figure 7.8: The performance of the deaf (N=41) and hearing (39 HoH and 10 HoD) participants on the 8 visemic minimal pair items, and the 12 non-visemic items (reference line indicates chance level at 50% correct; error bars show a 95% confidence interval)

To further investigate the impact of visemic similarity on the groups' performances, the items were broken down by word position (see Figure 7.9). The deaf group

performed significantly above chance on both the word-initial and word-final visemic items (WI: $t(40)=2.22$, $p<.05$; WF: $t(40)=5.55$, $p<.001$). The HoD group's performance was above chance for the word-final, but not the word-initial items (WI: $t(9)=.802$, $p=.44$, NS; WF: $t(9)=4.71$, $p<.002$); and the HoH group's performance was at chance for both word positions (WI: $t(38)=-1.96$, $p=.06$, NS; WF: $t(38)=1.14$, $p=.26$, NS).

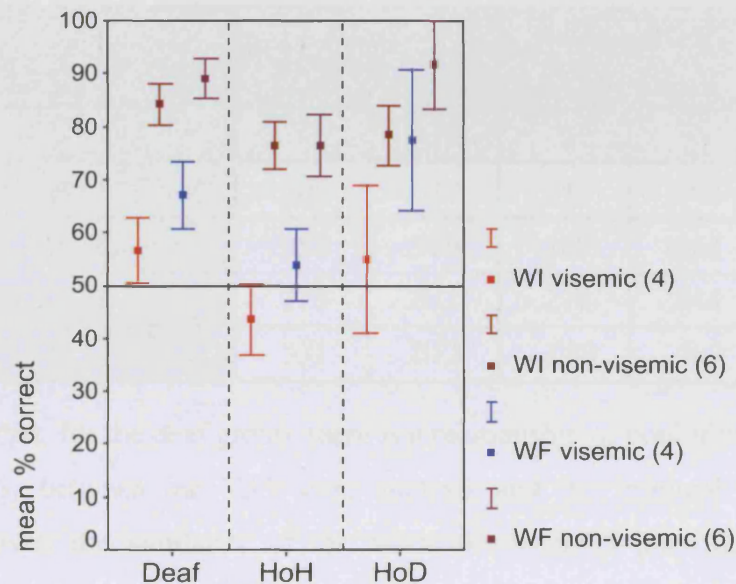


Figure 7.9: The performance of the deaf ($N=41$) and hearing (39 HoH and 10 HoD) participants on the word-initial (WI) and word final (WF) visemic and non-visemic minimal pair items (reference line indicates chance level; error bars show a 95% confidence interval)

7.11 Correlations between speechreading measures

Both of the additional subtests were expected to correlate with performance on the TAS core subtest, but were predicted to be related to different aspects of the test. The minimal pairs subtest was designed to tap the analytical, low-level segmental aspects of speechreading. This subtest was predicted to be related to the single word subtest particularly (they are very similar tasks) and to the TAS as a whole if participants approached the task analytically (bottom-up) and attempted to identify the phonemes in the speech. The focus task taps one of the prosodic cues that may be used in lexical segmentation. This task was expected to correlate with the sentence and, particularly, the connected speech subtests because these are the levels at which lexical segmentation is necessary.

7.11.i Minimal Pairs

Table 7.11 shows the correlations between performance on the TAS core subtests, both combined and individually, and the minimal pairs subtest for the deaf and HoH participants.

Table 7.11: Correlations (1-tailed) between performance on the minimal pairs subtest and on the TAS core subtests (blue: 1-tailed $p < .05$; red: 1-tailed $p < .02$)

	Deaf (N=41)		Hearing (HoH) (N=41)	
	r	p	r	p
TAS core subtests	.300	.028	.246	.065
Words	.058	.360	.249	.063
Sentences	.275	.041	.277	.044
Stories	.331	.017	-.039	.407

It can be seen that, for the deaf group, there is a relationship of borderline significance (1-tailed $p < .05$) between the TAS core subtests and the minimal pairs subtest. Surprisingly given the similarity of the tasks, the minimal pairs subtest did not correlate with the word subtest. The strength of the correlation increased as utterance-length increased, reaching borderline significance with the sentence subtest, and a stronger correlation ($p < .02$) with the story subtest. However, these correlations do not survive controlling for a language measure such as expressive English vocabulary²⁹ (TAS core subtests: $r = .128$, d.f.=38, $p = .432$; story subtest: $r = .136$, d.f.=38, $p = .404$), or for performance on the focus subtest (TAS core subtests: $r = .138$, d.f.=37, $p = .401$; story subtest: $r = .113$, d.f.=37, $p = .495$).

For the hearing group, the correlation between the minimal pair subtest and the TAS core subtests combined fails to reach significance (1-tailed $p = .065$), although the correlation between sentence and minimal pair subtests does reach borderline significance (1-tailed $p < .05$).

These results give limited support for the hypothesis that the skills measured by the minimal pairs subtests are related to general speechreading skill as measured by the TAS core subtest. The correlations, are not, however, as strong as would be expected if these speechreaders were using a completely bottom-up approach to the TAS core subtests. Further evidence against the bottom-up hypothesis for the deaf group is

²⁹ This measure is described fully in Chapter 9.

provided by investigating these correlations within subgroups of deaf participants. When they are grouped according to hearing aid use or language preference (Table 7.12), it can be seen that the pattern of significant correlations seen in Table 7.11 is evident only for the subgroups who scored *less* well on the TAS core subtests: those who did not wear hearing aids, and those who preferred to use some English in their everyday communication. For the subgroups that performed better on the TAS core subtests, there are no significant correlations between performance on the minimal pairs task and on the TAS core subtests.

Table 7.12: Correlations (1-tailed) between performance on the minimal pairs subtest and on the TAS core subtests for the deaf participants grouped by hearing aid use and language preference (blue: 1-tailed $p < .05$; red: 1-tailed $p < .02$)

		Hearing Aids		Preferred Language	
		Yes	No	Some English	BSL
TAS core subtests	r	.183	.445	.088	.441
	p	.202	.033	.394	.009
Words	r	.277	-.225	.119	.116
	p	.101	.185	.357	.274
Sentences	r	.052	.439	-.248	.388
	p	.406	.035	.219	.019
Stories	r	.135	.443	.137	.397
	p	.270	.034	.336	.017

Two predictions were made regarding correlations with the minimal pair items grouped by word position. First, since the perception of word initial consonants may facilitate segmentation of the speech stream (see section 3.2.ii), performance on the WI items was predicted to correlate with performance on the sentence and story subtests. As Table 7.13 shows, the hearing data lend partial support to this hypothesis: the correlation between performance on the WI items and the sentence subtest reached borderline significance (1-tailed $p < .05$). There was, however, no significant correlation with the story subtest for the hearing group, or with either the sentence or story subtests for the deaf participants. For the latter, performance on the WF items correlated significantly with performance on the sentence subtest.

Table 7.13: Spearman's rho correlations (1-tailed) between performance on the word initial (WI), word medial (WM) and word final (WF) minimal pairs items and on the other speechreading subtests (blue: 1-tailed $p < .05$; red: 1-tailed $p < .02$)

			Deaf			Hearing (HoH)		
			WI	WM	WF	WI	WM	WF
TAS core subtests	Word	rho	.196	.007	-.007	-.081	.187	.249
		<i>p</i>	.109	.483	.483	.312	.127	.063
	Sentence	rho	-.201	.285	.446	.272	.136	.080
		<i>p</i>	.104	.036	.002	.047	.204	.315
	Story	rho	-.018	.276	.210	-.159	.134	.050
		<i>p</i>	.456	.041	.094	.167	.207	.381
Focus subtest		rho	.040	.348	.108	-.039	-.180	.062
		<i>p</i>	.403	.014	.254	.409	.140	.356

Secondly, performance on the word medial items (which test the ability to discriminate between vowels within words) was predicted to correlate with performance on the focus subtest, since information that indicates focus is carried by the intensity and duration of the stressed word's vowel. The deaf group's data support this hypothesis: there is a significant correlation between performance on the focus subtest and on the WM minimal pairs items for this group (1-tailed $p < .02$; see Table 7.13). This correlation is not, however, evident for the hearing group. This may indicate that the deaf speechreaders made use of the changes in the vowel duration to identify the stressed word. The hearing speechreaders, on the other hand may be using alternative information, such as head or facial feature movements to enable them to perform the focus task.

7.11.ii Focus

Performance on the focus subtest correlated significantly with performance on the TAS core subtests for both the deaf and hearing groups (see Figure 7.10 and Table 7.14). For the deaf group, the focus subtest score correlated significantly with every level of the TAS, and, as expected, the strength of the correlation increased as the utterance length, and therefore the segmentation requirements, of the core subtests increased (words < sentences < stories). In contrast to the minimal pairs task, the relationship between the focus task and the TAS core subtests survives controlling for performance on the minimal pair subtest ($r = .670$, $d.f. = 37$, $p < .001$).

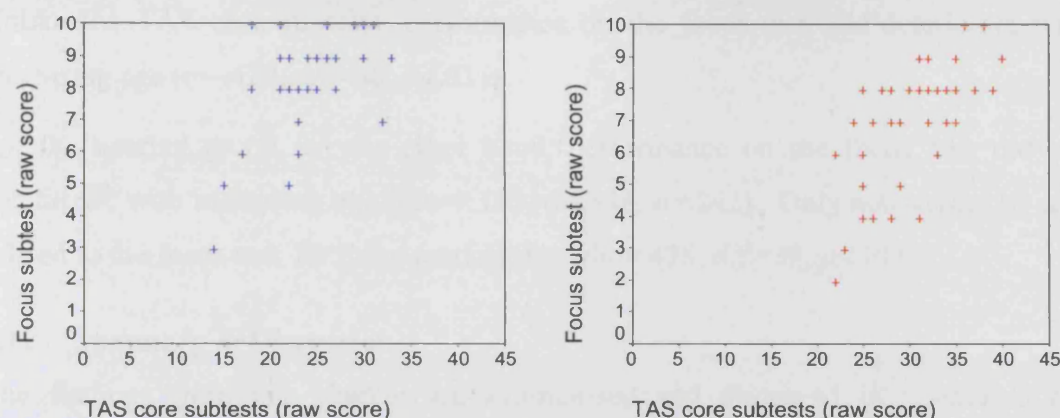


Figure 7.10: Scatter plots illustrating the relationship between performance on the focus task and on the TAS core subtests for the deaf (left-hand graph) and hearing (right-hand graph) participants

For the hearing group, the focus subtest correlated significantly with the word- and sentence-level subtests, but not with the story-level subtest, which the hearing group found difficult (their scores range from 0% to 53.3% correct, with a mean of 25.6%). The expected increase in strength of correlation with increasing length of linguistic level was not evident for this group.

Table 7.14: Spearman's rho correlations (1-tailed) between performance on the focus subtest and on the TAS core subtests (red: 1-tailed $p < .02$)

	Deaf (N=40)		Hearing (N=38)	
	rho	p	rho	p
TAS core subtests	.685	.000	.431	.003
Words	.332	.018	.436	.003
Sentences	.572	.000	.344	.017
Stories	.595	.000	.003	.494

Performance on the focus task was affected by demographic variables in a similar way to the TAS core subtests. Within the deaf group, participants who used hearing aids ($t(38)=2.12$, $p < .05$), preferred to use some English in their everyday communication ($t(38)=2.89$, $p < .01$), or had achieved higher education ($t(38)=2.51$, $p < .02$) outperformed their peers on the focus task. In addition, task performance correlated significantly with risk-taking and impulsiveness ($r=.484$, d.f.=20, $p < .05$).

Unlike the TAS core subtests, performance on the focus task *did* deteriorate with increasing age ($r=-.420$, $d.f.=40$, $p<.01$).

For the hearing group, on the other hand, performance on the focus task did not deteriorate with increasing age ($\rho=-.195$, $d.f.=38$, $p=.242$). Only non-verbal IQ was related to the focus task for these participants ($\rho=.428$, $d.f.=38$, $p<.01$).

7.12 Summary & Discussion

The findings from this chapter are summarised and discussed in answer to the following questions:

Minimal pairs

- Why did the deaf participants outperform their hearing peers on the minimal pairs task?
- Can deaf and/or hearing adults speechread ‘sub-visemic’ information?
- Could word final information be particularly useful in speechreading?
- Is there evidence for bottom-up processing?
- Why do the single word and minimal pair subtests not correlate?

Focus

- Can prosody be perceived through vision alone?
- Why did the hearing participants outperform their deaf peers on the focus task?
- What do these findings suggest about the segmentation of the speech stream?

7.12.i Why did the deaf participants outperform their hearing peers on the minimal pairs task?

The hearing participants were expected to outperform the deaf participants on the minimal pairs subtest as a result of their predicted superior phonological coding and processing skills. One (unlikely) possible explanation for the initially surprising result that the deaf participants outperformed their hearing peers is that this group of deaf adults have unusually distinct and well specified phonological representations like those of hearing adults, and were able to make use of these in the minimal pairs task. This possibility will be investigated in Chapter 9, where the participants’ performance on phonological awareness tasks will be investigated.

A more probable possibility is that the deaf adults were not restricted by their impoverished phonological processing skills in responding to the minimal pair items, but were instead processing them at a whole-word level, and were able to make use of

all of the visually discriminatory features across the word in identifying their response. Given this assumption, the deaf participants' experience at interpreting the information in visually perceived speech may enable them to complete the minimal pairs task more accurately than their hearing peers.

7.12.ii Can deaf and/or hearing adults speechread 'sub-visemic' information?

Considered as a group, the deaf participants included in this research *were* able to identify which of a pair of words was spoken with above chance-level accuracy when the words differed only in one phoneme from the same visemic category (e.g. win / wing). They were able to do this whether the confusing phoneme was word initial or word final. It could be said, therefore, that they were able to speechread 'sub-visemic', or 'sub-PEC' (Auer & Bernstein 1997) information.

The hearing participants with hearing parents (HoH), on the other hand, performed at chance on these items. They showed no evidence of being able to speechread 'sub-visemic' information. This suggests that visemic / PEC classification differs as a function of hearing status and/or speechreading skill. Speechreaders who are deaf, or more skilled, may be able to perceive more, and more distinctive, visemic categories (PECs) than those who are hearing.

The hearing participants with deaf parents (HoD) fell between the other two groups: they performed above chance-level on the word-final visemic items, but at chance on the word initial ones. This group showed an ability to speechread some sub-visemic information.

No conclusions can be drawn regarding the relative difficulty of word-initial and word-final visemic items because there were only four of each. Similarly, the findings regarding the relative difficulty of the items grouped by word position (WI, WM, WF) cannot be generalised because of the limited number of items. However, the relative performance of the groups is interesting: the two groups who performed well on the task as a whole performed relatively well on the WF items.

7.12.iii Could word final information be particularly useful in speechreading?

The deaf and HoD groups, that is, the groups that achieved superior speechreading skills on the TAS core subtests and on the minimal pairs task, showed relatively higher scores on the word final minimal pairs items than the HoH group. This difference was particularly noticeable for the small HoD group (see Figure 7.7, pg. 227). It is possible that this relative skill in identifying words using word final

phonological information contributes to the deaf and HoD groups' superior speechreading skill. The significant correlation between performance on the word final minimal pair items and on the sentence subtest of the TAS for the deaf group supports this suggestion.

7.12.iv Is there evidence for bottom-up processing?

The deaf group show comparatively superior performance on the minimal pairs subtest. However, the strong correlation that would be expected if they were using a completely 'bottom-up' approach to speechreading is not evident. The deaf group's superior ability on the minimal pairs subtest may reflect their good lexical-level speechreading. A word is not made up of phonemes like beads on a string: the phonemes blend into each other. Correspondingly, the difference between two minimal pair words is not only carried in the phoneme in which they differ. The single phoneme difference affects the entire word. Deaf people may be especially good at using all of the visual phonotactic information available to identify words.

7.12.v Why do the single word and minimal pair subtests not correlate?

A strong correlation was expected between these two subtests because they are very similar tasks: both require the speechreader to watch a silent video of a talker saying a single word, and then to click on the picture that matches that word. There are, however, four differences between the tasks:

1. In the minimal pairs task, but not the word subtest, a written word is provided with each response picture to remove any ambiguity over the picture labels.
2. The distracters in the word subtest were chosen so that no two were obviously visually alike when spoken: there were no close distracters. The distracters in minimal pairs task on the other hand, are, by the nature of the task, very similar to the targets.
3. There are five distracters in the word subtest, and only one in the minimal pairs task.
4. The item order is randomised in the minimal pairs task, but fixed in the word subtest.

It may be that these differences resulted in the speechreaders using different skills or strategies to achieve each task. In the minimal pairs task, for example, the written word, combined with the reduced number of distracters may remove the *need* for the speechreader to use the speechread signal to activate potential items in the lexicon:

these could be activated (or the majority of potential items discarded) unambiguously through the response pictures alone. The task is only to decide between them. The word subtest, however, does not require simply word-identification based on an immediately obvious choice.

Both tasks were expected to depend on bottom-up processes of phoneme/viseme identification leading to lexical activation. If, instead, the deaf adults speechread at a whole-word level, without success resting on the serial identification of the constituent phonemes/visemes, then, given the differing information available from the response screen for each task, the lack of correlation between them is not surprising.

7.12.vi Can prosody be perceived through vision alone?

One aspect of prosody, sentence focus, *can* be perceived through vision alone. All of the groups of participants (deaf, HoH & HoD) included here were able to respond to the focus task with above chance-level accuracy.

7.12.vii Why did the hearing participants outperform their deaf peers on the focus task?

The deaf participants were expected to perform better than the hearing group on the focus subtest, because it was anticipated that deaf adults might be better at detecting prosodic information from facial expressions. In fact, this was the only speechreading task at which the hearing participants outperformed the deaf participants. The presence of a significant correlation between performance on the focus task and on the word medial minimal pairs items for the deaf but not for the hearing participants suggests that the two groups may approach the task differently. The deaf speechreaders may make use of the visible changes in the vowel duration to identify the stressed word (hence the correlation with the word medial minimal pairs, and the finding that they responded more accurately to the male talker for both of these subtests). The hearing speechreaders, on the other hand may be using alternative information, such as head or facial feature movements to enable them to perform the focus task. This implies that, in auditory or auditory-visual identification of focus, hearing adults rely on acoustic rather than visible aspects of (especially) vocalic features. This would not be surprising because vowel formants are acoustically very robust. In addition, findings such as that of a temporal alignment between head movements and voicing onset (Munhall et al. 2004) suggest that head movements are

likely to carry the required information. The hearing group's superior performance on this task is therefore likely to reflect their audiovisual experience of focus. The information carried in this prosodic information is auditorially salient and meaningful, but has no direct parallel in British Sign Language. The differences in meaning conveyed through focus in spoken English are conveyed through changes in word order in BSL. Accordingly, deaf people who chose to use BSL alone as their preferred communication mode performed less well on the focus task than those who used some English ($t(38)=2.81$, 2-tailed $p<.01$). The assumption that deaf and hearing people are making use of different information to perform the focus task could be investigated further by running the task with the mouth movements overlaid on otherwise static facial images. If deaf speechreaders tend to use vowel duration, and hearing speechreaders, facial feature movements, in responding to the focus task, this modification should impair the performance of the latter group more than the former.

7.12.viii What do these findings suggest about the visual segmentation of the speech stream?

The sentence, and, particularly, the story subtests of the TAS require the speechreader to segment the perceived signal. Two predictions have been investigated here regarding segmentation.

First, that word onsets are recognised in initial parsing (Sanders & Neville 2003a). The ability to speechread word onsets is assessed in the word initial items of the minimal pairs subtest. Performance on these items was therefore expected to correlate with performance on the sentence and story subtests. There was limited evidence of the role of word initial consonants in segmenting the visually perceived speech stream for the hearing group (the correlation between performance on the WI minimal pairs items and on the sentence subtest reached borderline significance), and none for the deaf group.

The second prediction concerns the 'metrical segmentation strategy' (Cutler & Norris 1988), which suggests that English listeners use knowledge of stress patterns to make an initial assessment of the location of the potential onsets of words in fluent speech. The focus subtest assesses speechreaders' ability to identify stress in speech. Performance on this subtest was therefore predicted to correlate with performance on the sentence and story subtests. In support of this hypothesis, performance on the focus task did correlate with performance on the sentence and story subtests for the

deaf participants. In addition, the strength of the correlation between the subtests and the focus task increased as the demand on segmentation increased. For the hearing group, there was a significant correlation between the focus task and the sentence subtest, but not the story subtest. Verbal feedback from the hearing participants during testing frequently indicated that they found segmenting the speech stream extremely difficult for the story items, and as a result guessed many of the items (this is born out in their low performance on this task). Since many of the hearing participants were unable to attempt to segment the speech stream for the story items, the lack of a correlation between performance on this subtest and a skill hypothesised to facilitate segmentation is not unsurprising.

Chapter 8

VISUAL PROCESSING AND SPEECHREADING

8.1 Introduction

In the previous two chapters, the speechreading abilities of deaf and hearing adults have been investigated largely as a function of their demographic characteristics. The following two chapters investigate further potential correlates of their speechreading abilities. Individual speechreading abilities have been linked with a range of cognitive and language-processing factors. However, the role of specifically visual abilities in relation to the processing of visible speech has been less studied, and is the focus of this chapter.

8.2 Introduction to Visual Processing

The visual system is divided into two largely parallel processing streams: the magnocellular and parvocellular pathways.

Table 8.1: An overview of the magnocellular and parvocellular systems

The MAGNOCELLULAR system	The PARVOCELLULAR system
Highly responsive to motion ³⁰ and to stimuli of low spatial frequency and contrast	Highly responsive to high illumination, colour information and to stimuli of high spatial frequency
Projects strongly (Neville & Bavelier 2000) to the... Dorsal visual pathway	Projects strongly (but not solely, see Stoner & Albright 1993) to the... Ventral visual pathway
Projects from V1 toward the posterior parietal cortex	Projects from V1 to anterior regions of the inferior temporal lobe
Includes areas important for the processing of spatial location and motion information	Includes areas important for processing form and colour information
There is anatomical evidence that the visual periphery is represented most strongly along the dorsal visual pathway	Central space is largely represented along the ventral visual pathway: its tracts are more numerous in foveal than peripheral vision

³⁰ In contrast to parvocells, cells of the magnocellular stream have large cell bodies and thickly myelinated axons with rapid membrane dynamics and high conduction velocities dedicated to stimulus timing and the detection of rapid change.

These anatomically defined pathways are generally considered to correspond to the psychophysically defined transient and sustained systems. Although the correspondence is not perfect, it is fairly strong (Lennie 1980; Schiller et al. 1990). The two pathways start with different classes of ganglion cells in the retina and remain fairly separate up to and into some parts of the cortex. Table 8.1 provides an overview and comparison of the two.

8.3 Do deaf people see better?

There is a popular myth that deafness leads to enhancements in the other senses, including vision. In reality, however, there does not appear to be an overall enhancement of vision or visual-perceptual skills in deaf people. In fact, there may be a higher incidence of a range of visual problems in the deaf population compared to the hearing population (Parasnis 1998). Congenital deafness and the native use of a signed language (such as BSL) do, however, result in highly specific, limited enhancements in visual processing, and these are considered below.

8.3.i Changes in visual processing following congenital deafness

Congenital auditory deprivation is associated with specific changes in visual cognition. Deaf individuals show enhanced performance in processing visual stimuli that are in motion or are presented in the peripheral (but not in the foveal) visual field and require attentional selection (Armstrong et al. 2002; Bavelier et al. 2000; Bosworth & Dobkins 2002; Loke & Song 1991; Neville et al. 1983; Neville & Lawson 1987a; Neville & Lawson 1987b; Neville & Lawson 1987c; Parasnis & Samar 1985; Proksch & Bavelier 2002). In addition, there is fMRI evidence that congenital deafness alters the cortical organisation of motion processing, especially when attention is required (Tomann et al. 1998). Since both motion processing and peripheral vision are predominantly magnocellular visual functions, mediated through the dorsal pathway (see Table 8.1), it has been suggested that magnocellular / dorsal visual functions might be especially susceptible to the effects of deafness (Armstrong et al. 2002; Bavelier et al. 2000; Stevens & Neville 2006). Accordingly, Neville and Bavelier (1998) reported ERP evidence of enhanced responses to stimuli designed to selectively activate the magnocellular system (but not to those designed to activate the parvocellular system). However, not all dorsal visual pathway functions are affected by early deafness. For example, sensory thresholds for motion direction and velocity do not differ in deaf and hearing individuals, even when tested in the periphery

(Bosworth & Dobkins 1999; Brozinsky & Bavelier 2004). It appears then that changes in visual processing in congenitally deaf individuals are evident mostly under conditions of attention (see Bavelier et al. 2006 for a review).

Deafness leads to changes in the spatial distribution of visual attention, with enhanced allocation over the peripheral visual field. Greater recruitment of the motion-selective area MT/MST has been observed in deaf than in hearing individuals when they were attending to the peripheral visual field (the 2 groups were comparable when monitoring the central field, or when participants viewed stimuli passively) (Bavelier et al. 2000; Bavelier et al. 2001; Fine et al. 2005). This reflects heightened sensitivity to peripheral events in deaf people. Behavioural evidence supports this finding: deaf individuals have been found to show greater attention at peripheral locations, whereas in hearing people attention is greatest in the centre of the visual field. Deaf individuals are more distracted by peripheral distracters than hearing individuals, and are less distracted by central distracters (Proksch & Bavelier 2002).

In summary, the results of a number of studies using a range of paradigms suggest that, in the absence of hearing, visual compensatory changes occur such that visual functions (such as peripheral and motion processing) that would normally benefit from convergence with auditory input (Bavelier et al. 2006) are enhanced under attentionally demanding conditions. In the absence of audition deaf people must rely on vision to orient to new incoming information, possibly resulting in an enhanced sensitivity of visual orienting mechanisms. Motion is usually associated with sound; the visual perception of motion becomes more functionally important in the absence of perception of the associated sounds (that is, hearing people can hear moving things, deaf people *have* to see them). People who are deaf may also devote greater processing resources to monitoring the peripheral visual field because they cannot use audition to monitor extrapersonal space.

8.3.ii Changes in visual processing following early exposure to sign language

The native use of a sign language (such as BSL or ASL) also leads to changes in visual processing. Comparisons of deaf and hearing native signers have indicated that that these changes are separate from those that follow congenital deafness. The enhanced peripheral processing seen in deaf individuals is not seen in hearing native signers. However, the use of a sign language does lead to a change in the lateralisation of the motion detection system (MT/MST): hearing (non-signing)

individuals can detect motion direction more accurately in the left than in the right visual field, and show greater recruitment of the motion areas in the right hemisphere than in the left hemisphere during motion processing, but native signers (deaf and hearing) show the opposite pattern (Bavelier et al. 2001; Bosworth & Dobkins 1999; Bosworth & Dobkins 2000; Neville & Lawson 1987c). Signed languages (such as ASL and BSL) rely heavily on the analysis of hand motion; the co-occurrence of this and language processing leads to greater motion sensitivity in the language-dominant left hemisphere.

Native signers have also been shown to exhibit enhanced facial processing (Bettger et al. 1997), spatial construction and transformation of objects (Bellugi et al. 1989), mental imaging and rotation (Emmorey et al. 1993; Emmorey et al. 1998), and gestalt completion (Siple et al. 1978).

People who are congenitally deaf, especially those who are native signers, may therefore perceive the movement aspects of the visual speech signal more efficiently than their hearing peers, and may make greater use of peripherally perceived information that may give additional clues about the message being conveyed.

8.4 The Visual System & Speechreading

“It might be assumed that peripheral vision might be important to the speechreader” (Berger 1972c, pg. 112)

To date, individual differences in speechreading skill have been investigated mainly in relation to specific cognitive and psycholinguistic factors, rather than visual ones (see Chapters 3, 6 and 9). There is no previous literature concerning a relationship between speechreading and magnocellular or parvocellular visual processing. There is, however, some evidence for the importance of both form and motion processing in speechreading (see section 3.4.i). Visual stimuli which contains only dynamic information, such as point light displays (Rosenblum et al. 1996), and images blurred by low-pass spatial frequency filtering (Munhall et al. 2004), provide audiovisual gain for speech perception. However, people are able to identify speech sounds without any dynamic information available: they are able to identify vowels and consonants from still photographs (Campbell 1986; Campbell et al. 1986). In addition, both time-independent (photographs of a person articulating a sound) and time-varying (point light displays) visual information has been found to influence auditory perception in McGurk effect tasks (Campbell 1996; Cathiard et al. 1992; Cathiard & Tiberghien

1994; Rosenblum & Saldana 1996). However, neuropsychological dissociations suggest that it is the dynamic characteristics of seen speech that may be more important in audiovisual and visual speech processing: one patient with an acquired cortical blindness for visual movement, who was able to identify speech-patterns from photographs, was unable to speechread natural speech (Campbell et al. 1997). A second patient, with a profound deficit in identifying visual forms, who was unable to identify speech gestures from photographs, was susceptible to the McGurk illusion (Campbell & Perrett 1992). In addition, Yakel and Rosenblum (Yakel 2000; see Rosenblum 2005) have shown (based on an auditory speech study, Strange et al. 1983) that the lipreading of VCV bisyllables was best when *only* the time-varying, co-articulated portions of the syllable were visible. Having sight of the relatively unchanging, sustained mouth pattern of the vowel-nucleus of each syllable impaired accurate speechreading compared with viewing clips where these portions of the articulation were excised and replaced with a dark screen.

It appears, then, that it is the dynamic properties of speech that are critical for visual or auditory-visual speech perception. That is not to suggest that visual form information has *no* value in speechreading. Point light speech stimuli are not as informative as fully illuminated talking face stimuli (Rosenblum & Saldana 1998), and, certainly, the viewer has to have sight of the mouth, lips, teeth and tongue of the talker to gain most from speechreading (Summerfield 1979). This may, however, only set a lower limit on the visibility characteristics of the talker's face for speechreading.

8.5 Experimental Questions

The study reported in this chapter explores the extent to which motion and form coherence sensitivity might relate to individual differences in speechreading ability in deaf and hearing adults. It addresses the following questions:

8.5.i Do deaf and hearing groups differ in their sensitivity to visual motion or form coherence?

Deaf participants are expected to show lower motion coherence thresholds than hearing participants following the findings of enhancements in magnocellular processing in congenitally deaf people described in section 8.3. There have been some, slight, indications that deaf adults can sometimes outperform matched individuals with normal hearing at some visual form detection tasks under attention-

demanding conditions (Rettenbach et al. 1999), and in the domain of face processing, one study found that face-features can be better recognized by Deaf than hearing adults (McCullough & Emmorey 1997). However, such positive findings are remarkable for their scarcity. No difference is expected, therefore, between the form coherence thresholds of the two groups.

8.5.ii Are individual differences in speechreading skill predicted by sensitivity to visual motion or form coherence?

A negative correlation is expected between motion coherence thresholds and speechreading score for both deaf and hearing participants, reflecting the salience of dynamic visual information in speech processing discussed above. The relationship between form coherence thresholds and speechreading is also of interest, but no predictions are made concerning an association with speechreading in either group.

8.6 Methods

8.6.i Participants

The motion and form coherence thresholds of twenty-four of the deaf participants and fifteen of the hearing (HoH) participants were tested. Their demographic characteristics and performance on the TAS core subtests are detailed in Table 8.2 (see also Appendices G and H, which show the tasks completed by the deaf and HoH participants respectively).

Table 8.2: Participants' demographic characteristics and speechreading performance

	Deaf (N=24)		Hearing (HoH; N=15)	
Gender (no. of females)	12 (50%)		9 (60%)	
Parental hearing status (no. of deaf parents)	11 (46%)		--	
Hearing aid use (no. who use hearing aids)	14 (58%)		--	
	Mean	(S.D.)	Mean	(S.D.)
Age (yrs;mths)	34;9	(8.10)	35;9	(15.72)
Non-verbal IQ (%ile)	82.7	(20.41)	80.9	(19.13)
Speechreading (TAS raw score) ³¹	29.5	(5.23)	23.6	(5.02)

³¹ The TAS core subtests data for these reduced groups remained normally distributed (deaf: Shapiro Wilk statistic = .948, df=24, $p=.244$; HoH: Shapiro Wilk statistic = .957, df=16, $p=.602$).

8.6.ii Materials

Similarly structured tests of visual motion (MOTDX v1.94) and form (FORM-F v.1.15) coherence detection were administered to determine psychophysical thresholds, following the procedures outlined by Hansen and colleagues (2001). The motion coherence task has been shown to be sensitive to a number of developmental conditions, including reading disability (Conlon et al. 2004 for review; Solan et al. 2003), autism (Milne et al. 2002; Spencer et al. 2000), and William's syndrome (Atkinson et al. 1997; Atkinson et al. 2003; Nakamura et al. 2002). As a test of sensitivity to global second-order motion, it has psychological validity and reliability and is sensitive to individual differences within and across a range of tested groups. The similarly structured visual form coherence task is usually administered in the same session as the motion coherence task, and follows an identical testing procedure. It can also be differentially sensitive to group differences (see e.g. O'Brien et al. 2002).

The tasks were administered to participants individually on a desktop computer with a 17-inch screen in a quiet, darkened room (mesopic conditions, not scotopic). Participants were seated 57 cm from the screen, they were not dark adapted, and no glare was apparent on the computer screen. For each task, participants saw the stimuli described below, with the percentage of coherently moving dots (motion coherence) or coherently arranged line segments (form coherence) varying across trials. After each trial, feedback was given. The usual auditory feedback provided in this task was replaced with visual feedback for this study to make the task fully accessible to all participants. A tick in the centre of the screen indicated a correct response, and a cross, an incorrect one.

For each test, demonstration mode stimuli (which had infinite stimulus durations) were used to explain the task to participants. Once they fully understood, ten test trials were administered as practice. Following this, the task was administered twice, giving two motion and two form thresholds for each participant. The thresholds indicated the lowest proportion of coherently moving dots or arranged line segments that could be perceived. The order of presentation of the two tasks was counterbalanced, and the tasks were separated by non-computer-based tasks (see Appendix J) to reduce eye strain.

Motion coherence: The stimulus was a standard random dot kinematogram (RDK) consisting of two horizontally adjacent panels of moving dots with a fixation cross centrally placed between them. Each panel contained 300 white dots of high Michelson contrast ($\sim 90\%$) superimposed on the black background of the computer screen. The dots were 1 screen pixel in size (approximately $0.1 \times 0.1^\circ$), and each panel was rectangular, subtending 100×120 pixels and separated horizontally by 50 pixels. One panel contained a variable proportion of target dots that moved coherently (at $7^\circ/\text{sec}$) to either left or right over successive screen refreshes, whilst the remaining noise dots in the panel moved with the same speed but in a direction that randomly changed between refreshes (Brownian motion). The other panel contained only noise dots. Participants were instructed to make a button press response to indicate which panel contained the coherently moving dots. They were told that there would be some trials on which they would be unsure, and that on these occasions they should guess. To prevent tracking of individual dots, the lifetime for each dot was fixed at three animation frames (85ms) after which time the dot was regenerated at a random position inside the same panel. Figure 8.1 shows a schematic illustration of stimuli from the motion task.

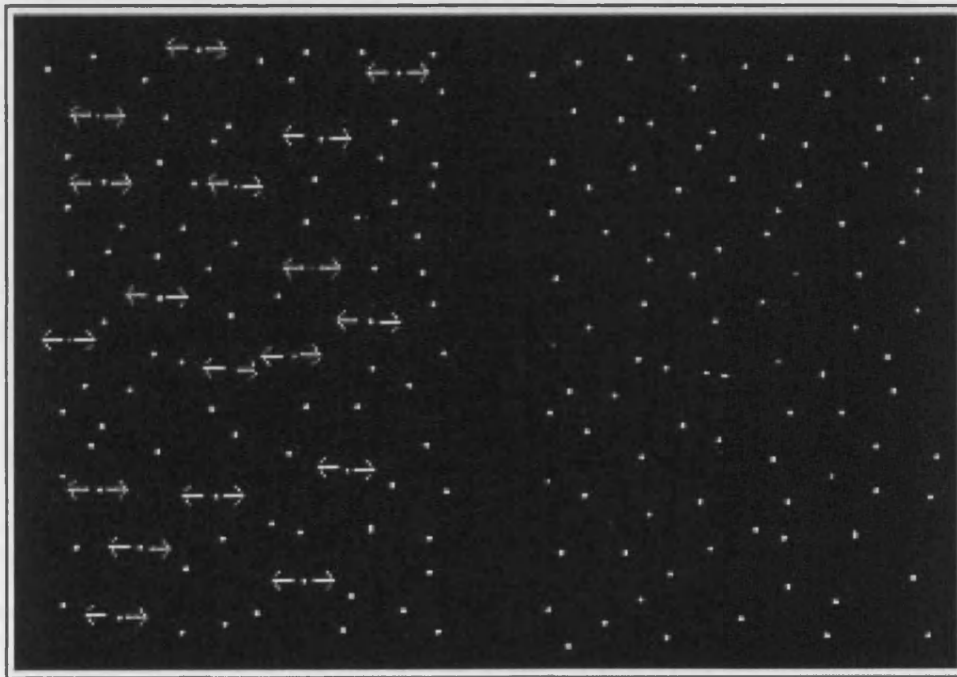


Figure 8.1: Schematic illustration of a random dot kinematogram used to identify the threshold of coherent motion detection

Form coherence: The form coherence threshold task was designed to be as similar as possible in application to the motion task. Two rectangular panels were presented side by side, matched in size and overall luminance to the motion task, with a fixation cross positioned centrally between them. Each panel consisted of 900 short, high contrast line segments, with each segment being 0.8° in length. In one panel there was a coherent form signal, defined by line segments that were oriented tangentially to imaginary concentric circles within an area of 8° diameters. Signal coherence was varied by modifying the percentage of aligned segments. At 75% coherence (the initial % coherence) therefore, three quarters of the line segments within the 8° boundary were aligned and the circle was easy to perceive. Segments outside the 8° area were orientated randomly. In the other panel, all segments were randomly orientated. As with the motion coherence task, participants were required to make a button press response to indicate which of the two panels contained the coherent form, and to guess if unsure. Figure 8.2 shows a schematic illustration of stimuli from the form task; the panel on the left shows the coherent form.

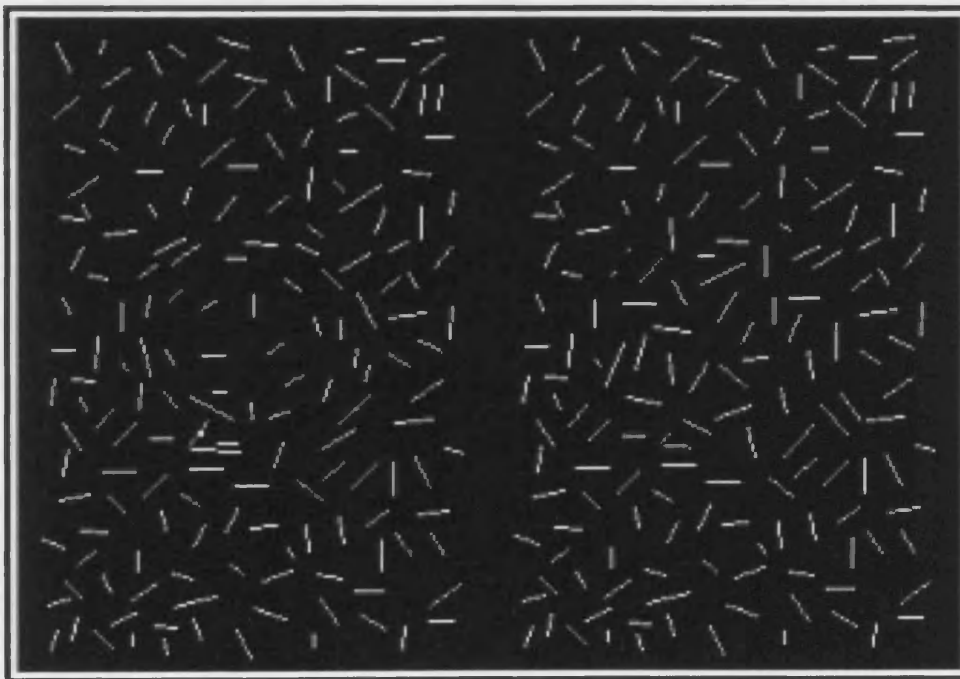


Figure 8.2: Schematic illustration of the form detection stimuli

In both tasks signal coherence was varied by modifying the percentage of coherent elements. Initial coherence was set at 75% and then adjusted using a weighted (1.5:0.5 dB ratio) 1-up, 1-down adaptive staircase (Kaernbach 1991). The procedure

terminated after 10 reversals and final threshold was calculated as the geometric mean of the last 8 reversal points.

Both the motion and the form task contained a number of catch trials (5% of the total number of trials). These were trials in which the form or motion was presented at an easily perceivable 75% coherence, and were included to identify trials on which factors such as participants' poor attention or incomplete understanding of the task affected their performance. Threshold measurements in which errors were made on 25% or more of the catch trials were considered invalid and excluded from the analyses.

8.7 Pre-analysis of visual coherence threshold data

8.7.i Motion Coherence

Catch trials: Only one participant (hearing) made errors on 25% or more of the catch trials in a threshold measurement. He made errors on 2 out of 8 catch trials on his first threshold measurement (but no catch trial errors on the second threshold). The first threshold (which was very high) was therefore discarded for that participant (this participant's thresholds are shown circled in purple in Figure 8.3). Three of the other participants (two deaf and one hearing) each made one catch trial error (9.09% to 10% of the total number of catch trials respectively). These threshold measures were not excluded.

Motion coherence measure: The mean of the two thresholds was taken for the rest of the participants, unless there was a large discrepancy (of over 15%) between the two – that is, where a participant performed considerably better on the second trial than the first. In this case the second value was taken, as this was more representative of the participant's true threshold. Plotting the 1st threshold against the 2nd for the deaf and hearing groups (Figure 8.3) reveals one deaf participant who showed this discrepancy (outlying case circled in green; Mahalanobis Distance = 9.64).

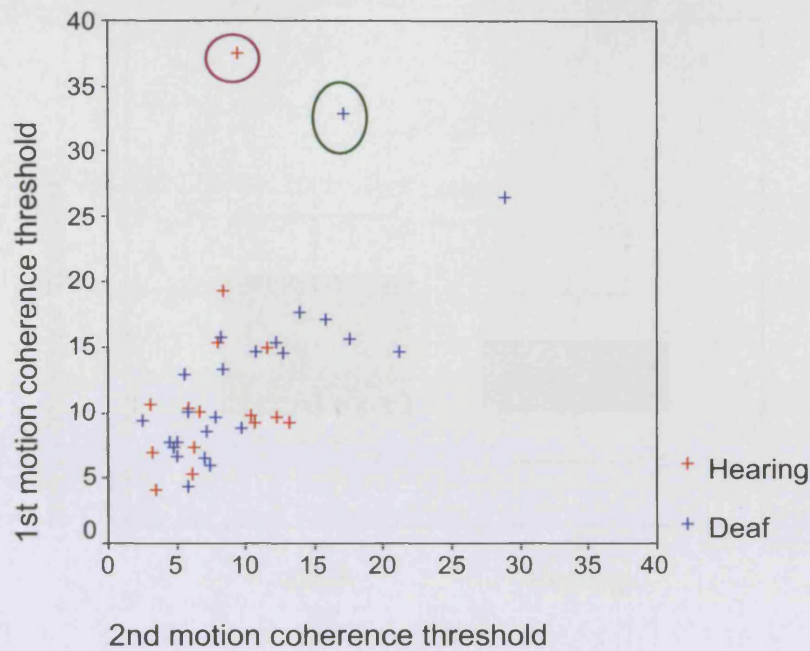


Figure 8.3: The relationship between the first and second motion coherence threshold measures for the deaf and hearing participants (1st thresholds were discounted for the circled cases)

Distribution: The resultant motion coherence data for the deaf group was significantly positively skewed ($z_{\text{skewness}} = 2.74$), and therefore not normally distributed (Shapiro Wilk statistic = .873, $df=24$, $p<.01$), with one outlier. The distribution of the data for the hearing group does not significantly differ from normal (Shapiro Wilk statistic = .979, $df=15$, $p=.960$). These data are illustrated in the box plots in Figure 8.4.

A logarithmic (to base 10) transformation of the data removed the positive skew for the deaf group ($z_{\text{skewness}} = 0.786$), and produced normal distributions for both groups (deaf: Shapiro Wilk statistic = .945, $df=24$, $p=.209$; hearing: Shapiro Wilk statistic = .946, $df=15$, $p=.465$), removing the outlier from the deaf group (see Figure 8.5).

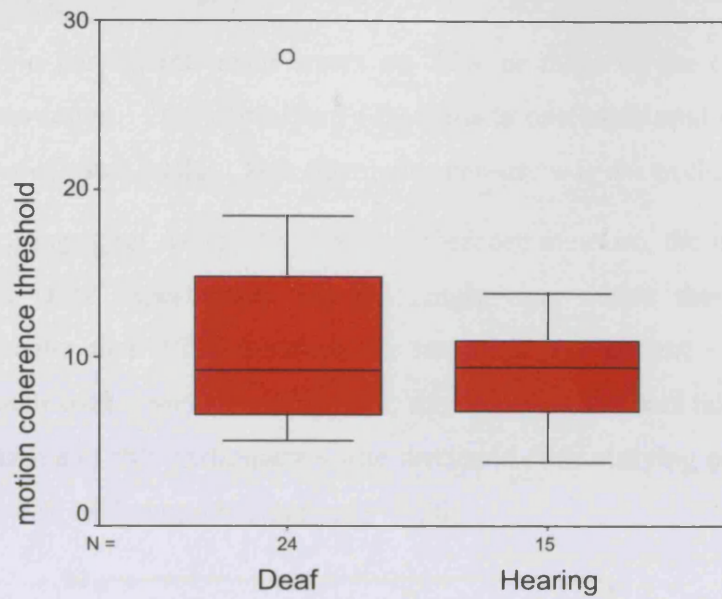


Figure 8.4: Box plots showing the distribution of the motion coherence threshold data for the deaf and hearing participants

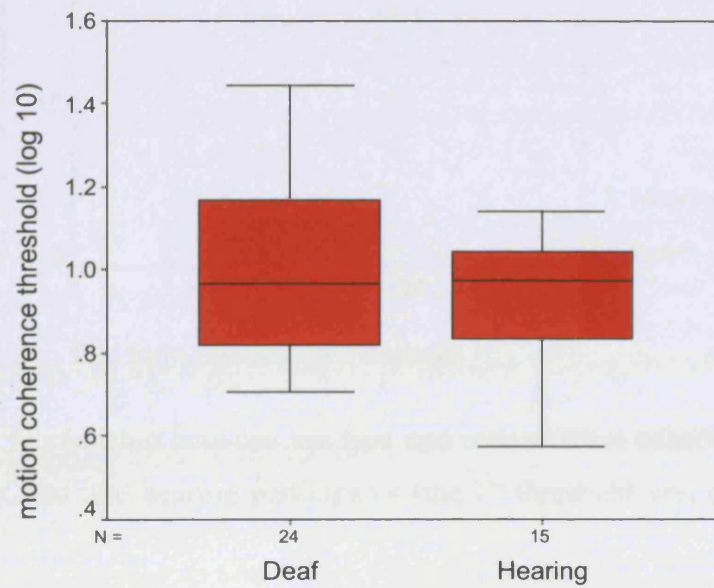


Figure 8.5: Box plots showing the distribution of the transformed motion coherence threshold data for the deaf and hearing participants

8.7.ii Form Coherence

Catch trials: No participant made errors on 25% or more of the catch trials in a threshold measurement. One participant (deaf) made one catch trial error (7.14% of the total number of catch trials). This threshold measure was not excluded.

Form coherence measure: As for the motion coherence measure, the mean of the two thresholds was taken, apart from for the single case where there was a large discrepancy (greater than 15%) between the two (this was not the same participant who made a catch trial error). For this case, the second value was taken, as this was more representative of this participant's true threshold (this outlying case is circled in green in Figure 8.6; Mahalanobis Distance = 9.20).

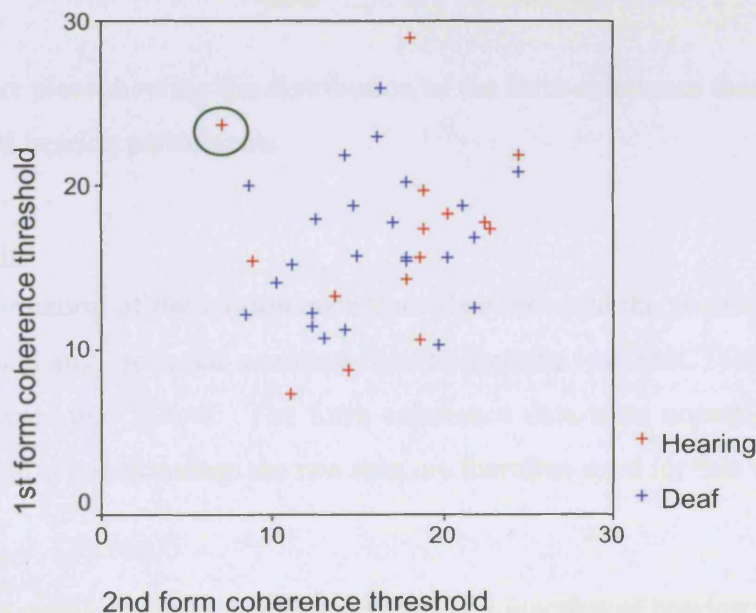


Figure 8.6: The relationship between the first and second form coherence threshold measures for the deaf and hearing participants (the 1st threshold was discounted for the circled case)

Distribution: The resultant form coherence data was normally distributed for both the deaf and hearing groups (deaf: Shapiro Wilk statistic = .973, d.f. = 24, $p = .738$, hearing: Shapiro Wilk statistic = .965, d.f. = 15, $p = .779$). These distributions are illustrated in Figure 8.7.

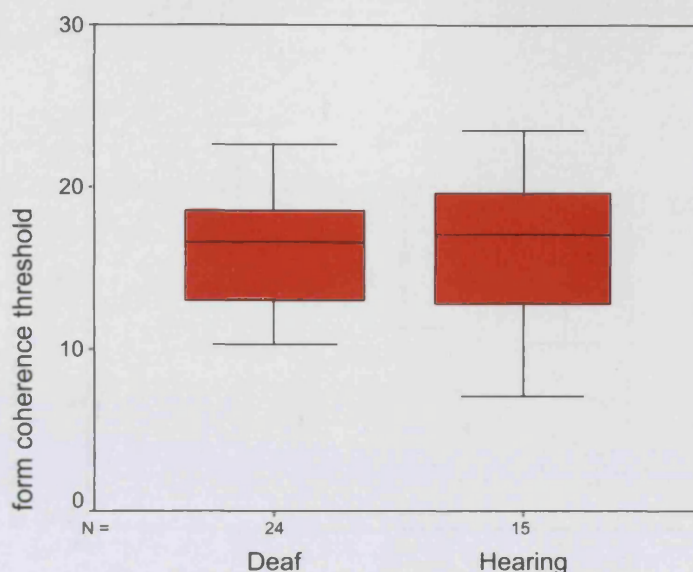


Figure 8.7: Box plots showing the distribution of the form coherence threshold data for the deaf and hearing participants

8.7.iii Summary

A \log^{10} transformation of the motion coherence data removed the positive skew in the deaf group's data and produced a normal distribution: the \log^{10} (MCT) data is used in all of the analyses that follow. The form coherence data were normally distributed and did not require transforming: the raw data are therefore used for this variable.

8.8 Results

8.8.i Did the visual detection thresholds differ as a function of hearing status?

There was no significant difference between the deaf and hearing groups' mean motion coherence thresholds ($t(37)=1.19$, $p=.242$, NS) or form coherence thresholds ($t(37)=0.15$, $p=.882$, NS) (see distributions illustrated in Figure 8.4 (pg. 251), and 8.7 respectively). Previous findings of magnocellular processing enhancements as a result of auditory deprivation have been found in Deaf native signers. The null finding here, did not, however, reflect the heterogeneous nature of the deaf group: eleven of the deaf participants were DoD native signers, and as Figure 8.8 shows, there was no difference between their motion coherence threshold and those of the other deaf or the hearing participants. The hypothesis of reduced motion coherence thresholds as a consequence of deafness is not therefore supported in this sample of participants.

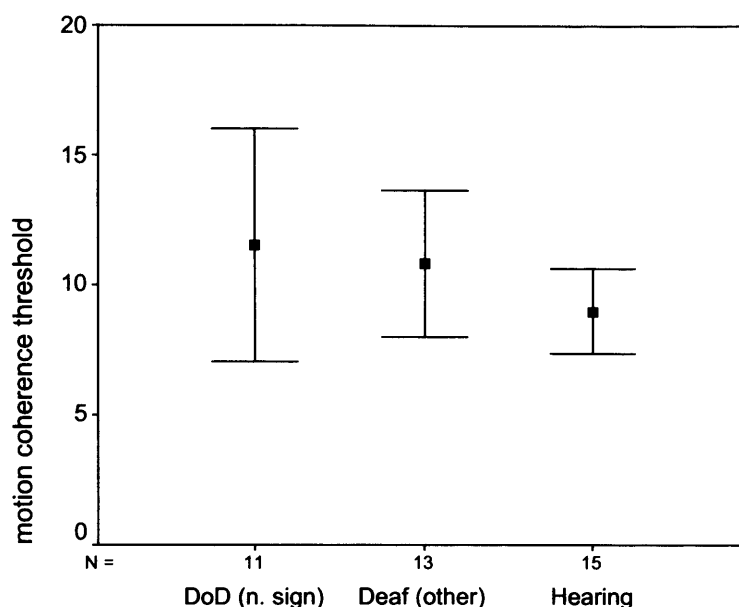


Figure 8.8: Error bars illustrating the motion coherence thresholds of the Deaf native signers, the other deaf participants and the hearing participants (error bars show 95% confidence interval)

8.8.ii Were the visual detection thresholds related to speechreading performance on the TAS?

It was anticipated that age would need to be controlled for in these correlations, since previous research has reported increased thresholds with increasing age, particularly for motion perception (Dengis et al. 1998; Gilmore et al. 1992; Snowden & Kavanagh 2006; Trick & Silverman 1991; Wojciechowski et al. 1995). However, there was no significant relationship evident between age and either measure of visual coherence detection in this sample of deaf and hearing adults (see Table 8.3). This is likely to reflect the relatively limited age range of the participants who completed these tasks: only one deaf and three hearing participants were aged over 50 years.

Table 8.3: Correlations between coherence thresholds and age for the deaf and hearing participants

	Motion		Form	
	<i>r</i>	<i>p</i>	<i>r</i>	<i>p</i>
Deaf (N=24)	.053	.807	.100	.641
Hearing (N=15)	.133	.635	.288	.299

It was not therefore necessary to include age as a control. Deterioration in the ability to detect visual coherence with increasing age would be expected in older adults due to presbyopic changes in the eye.

For both the deaf and hearing groups, there was a significant negative correlation between motion coherence threshold (\log^{10}) and performance on the TAS core subtests³² (deaf: $r=-.449$, $n=24$, $p<.05$; hearing: $r=-.543$, $n=15$, $p<.05$; see Figures 8.9 and 8.10 respectively). That is, lower thresholds on the motion coherence task were associated with better speechreading performance.

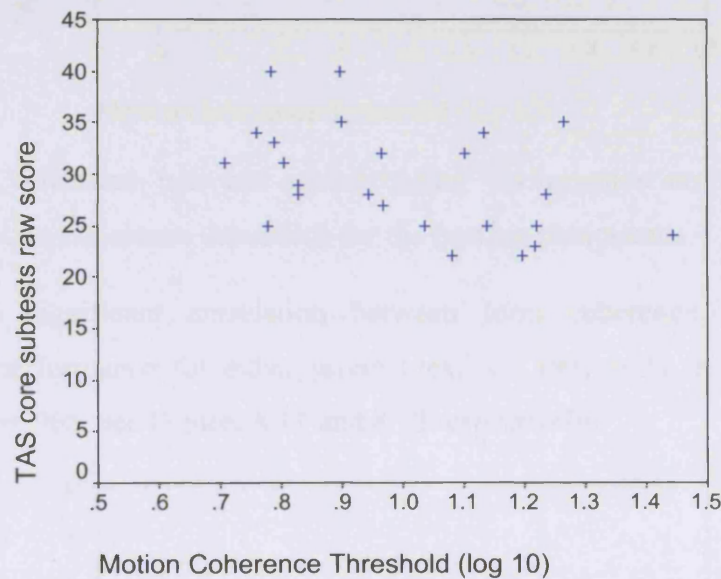


Figure 8.9: Correlation between speechreading performance on the TAS core subtests and motion coherence thresholds for the deaf participants

³² It should be noted, however, that when a more heterogeneous group of hearing participants was included, the relationship between motion coherence threshold and speechreading did not reach significance (Mohammed et al. 2005)

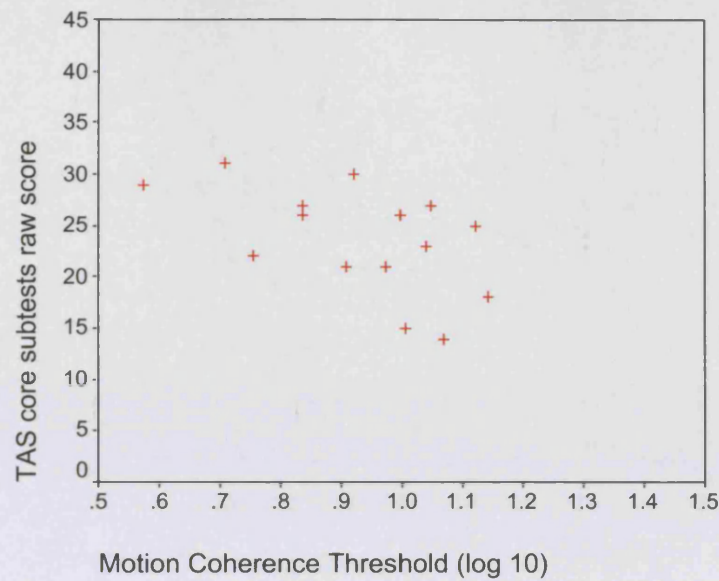


Figure 8.10: Correlation between speechreading performance on the TAS core subtests and motion coherence thresholds for the hearing participants

There was no significant correlation between form coherence threshold and speechreading performance for either group (deaf: $r=-.193$, $n=24$, $p=.367$; hearing: $r=-.012$, $n=15$, $p=.965$; see Figures 8.11 and 8.12 respectively).

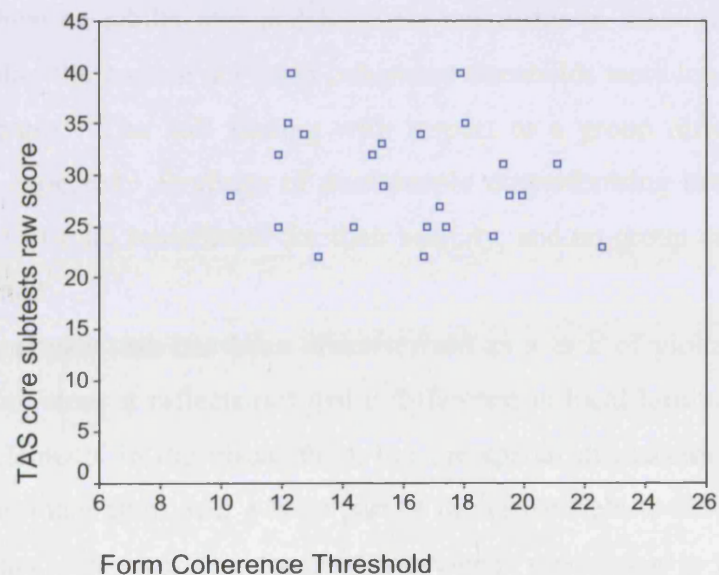


Figure 8.11: Correlation between speechreading performance on the TAS core subtests and form coherence thresholds for the deaf participants

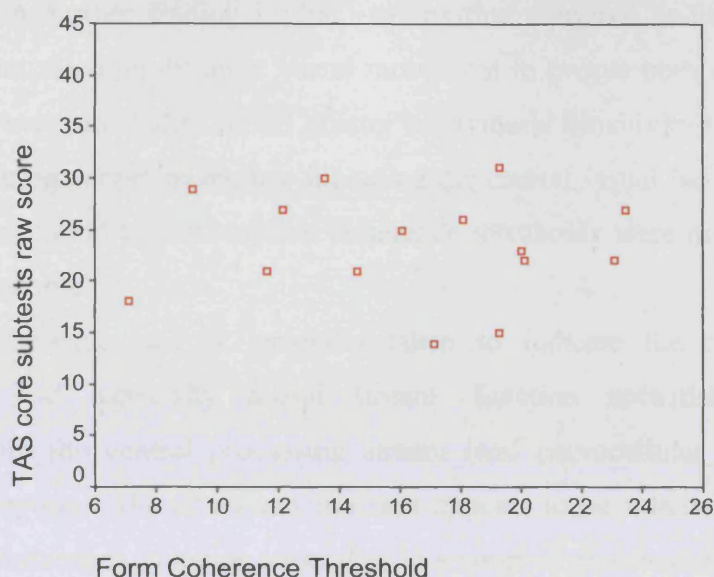


Figure 8.12: Correlation between speechreading performance on the TAS core subtests and form coherence thresholds for the hearing participants

8.9 Discussion

8.9.i Do deaf and hearing groups differ in their sensitivity to visual motion or form coherence?

The deaf and hearing adults included here did not differ in their visual coherence detection. Neither the motion nor form coherence thresholds were lower in deaf than hearing participants. The null finding with respect to a group difference in form coherence was expected. Findings of deaf people outperforming hearing on visual form detection tasks are remarkable for their scarcity, and no group differences were therefore predicted.

The motion coherence task has been characterized as a task of global second-order motion detection, since it reflects not just a difference in local luminance caused by movement of elements in the visual field, but the spatial displacement of a texture pattern requiring integration over a large part of the visual field to determine whether movement occurs. In turn, this form of movement processing is assumed to be associated with a range of higher order visual functions, including the perception of biological motion. In people born deaf, there is evidence that some forms of motion processing are enhanced as a result of early auditory deprivation. A robust finding is of greater behavioural and cortical sensitivity to movement, and of enhanced attention to motion in the peripheral visual field in deaf compared with hearing people (Armstrong et al. 2002; Bavelier et al. 2000; 2001; Neville & Lawson 1987a; see

section 8.3.i). A further finding is that regions that subserve audition in hearing people can be activated by dynamic visual movement in people born deaf (Finney et al. 2003). However, no studies report greater behavioural sensitivity to movement in deaf than in hearing people in regions including the central visual field. The present study was no exception to this: motion coherence thresholds were no lower in deaf than in hearing people.

The motion coherence task is generally taken to indicate the contribution of magnocellular, and especially dorsal stream, function notwithstanding some contribution from the ventral processing stream (and parvocellular processing) to movement perception. Dorsal stream function appears to be relatively sensitive to developmental influences, showing anomalies in a range of genetic conditions that are evident in infancy and childhood (Braddick et al. 2003). Dorsal stream function may develop differently in deaf than hearing people, so that deaf people can make relatively greater use of dynamic visual information than hearing people (Bavelier & Neville 2002), however, the enhancement is highly specific, and is seen only on tasks in the peripheral field (Bavelier et al. 2006).

8.9.ii Are individual differences in speechreading skill predicted by sensitivity to visual motion or form coherence?

A simple test of sensitivity to visual motion coherence was significantly associated with speechreading skill in both the deaf and hearing participants. A task of form coherence with identical testing procedures and very similar parameters showed no relationship with speechreading, despite evidence that visual speech forms deprived of natural visual movement can affect reports of auditory events (Cathiard & Tiberghien 1994), and can show patterns of cortical activation that do not differ greatly from those of naturally moving speaking faces (Calvert & Campbell 2003). It is unlikely that this null result simply reflects reduced sensitivity of the form coherence task compared with the motion coherence task. One study (O'Brien et al. 2002) has shown that dyspraxic children were impaired on form coherence but not motion coherence. It would seem, therefore, that individual differences in form sensitivity are less important for speechreading than sensitivity to movement. This adds support to the hypothesis that speechreading may rely critically on information carried in the dynamic, time-varying properties of articulation, rather than on time-independent articulator shapes (e.g. Rosenblum et al. 1996).

Chapter 9

THE LANGUAGE-RELATED CORRELATES OF SPEECHREADING

9.1 Introduction

Previous chapters have investigated speechreading as a function of factors that influence speechreading difficulty (Chapter 5), variables related to the speechreader (Chapter 6), different aspects of speechreading skill (Chapter 7), and low-level visual skills (Chapter 8). In this chapter, the deaf and hearing participants' performance on four language-related measures (digit span, vocabulary, phonological awareness and reading), and the relationships between those measures and speechreading, will be investigated. Reading, digit span, vocabulary and phonological awareness were selected because of their expected relationships with speechreading; each is considered separately in sections 9.1.i to 9.1.iv below.

9.1.i Reading

The relationship between speechreading and reading is particularly interesting because of the enormous educational, social, personal, and economic values of literacy. It is hoped that an increased understanding of the relationship between reading and speechreading may add to our understanding of why some deaf individuals attain good levels of literacy while many do not. Reading in deaf people, and its relationship with speechreading, was considered in depth in Chapter 2 (section 2.24). To summarise briefly, deaf people (children and adults) have repeatedly been shown to have poorer reading skills than their hearing peers (Allen 1986; Conrad 1979; DiFrancesca 1972; Dyer et al. 2003; Paul 2001; Trybus & Karchmer 1977). This largely reflects their impoverished language skills (such as those discussed in sections 9.1.ii to 9.1.iv below). Speechreading has previously been shown to be strongly correlated with reading in deaf adults (e.g. Bernstein et al. 1998a). In addition, a strong predictive relationship has been found between the two variables in developmental studies (Harris & Moreno 2006; Kyle & Harris 2006). The complex speechreading-reading relationship is likely to be reciprocal and to be mediated by other language skills, particularly phonological coding. It is possible that the relationship is also mediated by other factors, such as magnocellular processing. This

was found to be related to speechreading in Chapter 8, and is discussed below in relation to reading.

9.1.i.a) The Visual System and Reading

There is evidence of an association between reading disability and impaired magnocellular function (that is, degraded information processing in regions of the brain known to receive connections anatomically from M cells) for some people. It has therefore been suggested that impaired magnocellular visual function, as well as phonological deficits, may affect how children read (Cornelissen et al. 1998). This is particularly interesting in the light of the findings from Chapter 8, since a measure of magnocellular function was found to correlate with speechreading ability. It is therefore possible that magnocellular processing may be involved in the expected relationship between reading and speechreading.

Evidence of a selective magnocellular deficit in hearing people with specific literacy difficulties (dyslexia) comes from a number of varied studies. For example, Livingstone and colleagues (1991) found that the ventral, magnocellular layers of the lateral geniculate nucleus (LGN) from five adult reading disabled brains contained fewer, smaller cells than the comparable layers in five normal brains. There were, however, no group differences in the cell sizes of the parvocellular layers of the LGN. In psychophysical studies, adults with developmental dyslexia have been found to be less sensitive than control subjects at detecting coherent motion random dot kinatogram (RDK) stimuli, although the groups did not differ in their sensitivity to measures of static visual form coherence (Hansen et al. 2001; Talcott et al. 2000; Witton et al. 1998). Visual motion sensitivity (as measured with RDK stimuli) has been found to predict significant proportions of the variance in the non-word reading of both dyslexic and control adults (Witton et al. 1998). Dyslexic children have been found to show selectively slower magnocellular visual processing (as opposed to parvocellular processing) in comparison to non-dyslexic children (Sperling et al. 2003). Sperling and colleagues (2003) also found that magnocellular processing performance correlated with measures of orthographic skill (reading exception words aloud, and a forced-choice orthographic decision task) for both normal and dyslexic children. Cornelissen and colleagues (1998) showed a (non-linear) positive relationship between children's motion detection thresholds and the likelihood of them making letter errors on a reading task (errors containing sounds not represented

in the printed word). This result held when age, IQ and phonological awareness (on a spoonerism task) were taken into account. In addition, there is evidence of a relationship between magnocellular processing and reading ability in non-dyslexic readers: In a large study of primary school children (N=350) in which the group was divided into good and (relatively) poor readers (Talcott et al. 2002), there was a main effect of reading ability for coherent motion detection. The effect was not large, but does suggest that dynamic visual sensitivity is a small, yet significant predictor of literacy and component skills across the range of reading ability. There is also Visual Evoked Potential (VEP) evidence that adult *deaf* poor readers as a group show magnocellular system deficits in comparison to deaf good readers (Samar et al. 2002). This apparent relationship between magnocellular processing and reading may arise because dorsal stream areas are important for the generation and control of eye movements toward targets during visual search (Hansen et al. 2001). Impaired magnocellular function may also lead to uncertainty about where letters and letter features are positioned with respect to each other, leading to reading errors (Cornelissen et al. 1998).

Hypotheses:

- The reading age of the hearing participants is expected to be higher than that of the deaf participants.
- A significant positive correlation is expected between reading age and performance on each of the speechreading measures.
- A significant positive correlation is expected between reading age and other language-related skills, particularly phonological awareness.
- A significant negative correlation is expected between reading age and motion coherence threshold for the deaf and hearing participants. That is, more efficient magnocellular processing is expected to be associated with better reading.

9.1.ii Working Memory

“A good memory is a desideratum for speechreading” (Kitson 1915)

Working memory span, often measured by digit span, is the longest sequence of items a person can encounter once and immediately recall in the correct serial order. This measure of working memory was selected for use in the current study because it most clearly reflects the functioning of the phonological loop (Baddeley 2000). It depends

on the number of items that can be refreshed in the phonological loop before they decay. This depends in turn on how quickly the traces decay and on the rate of rehearsal.

Speechread information is sequential and linguistic, and is therefore best processed as such in the phonological loop (see section 3.7). The efficient functioning of the phonological loop is considered crucial to the efficient processing of spoken language, including visually perceived speech. Working memory capacity and speechreading ability may therefore be expected to correlate. Accordingly, high working memory capacity has been identified as a key feature in individual cases of exceptional speechreading skill (Lyxell 1994, the case of SJ; Rönnberg et al. 1999, the case of MM; although see Andersson & Lidestam, the case of AA). Verbal working memory has been shown to be better in good than poorer speechreaders of varied age and hearing status (e.g. Lidestam et al. 1999). Andersson and colleagues (2001) did not find the expected significant correlation between working memory span and speechreading. However their study included only fourteen very heterogeneous deaf participants: their age at onset of deafness, for example, ranged from 1 year to 61 years.

Deaf people are not able to make use of the phonological loop as efficiently as hearing people do (see section 3.7.ii). As a result, numerous studies over many years have shown that deaf children and adults tend to have shorter memory spans and perform less well in other short-term memory tasks than their hearing peers (e.g. Bellugi et al. 1975; Belmont & Karchmer 1978; Blair 1957; Hanson 1982; Kyle 1980b; Lichtenstein 1998; Pintner & Patterson 1917; Wallace & Corballis 1973).

Hypotheses:

- The hearing participants are expected to demonstrate larger digit spans than the deaf participants.
- A positive correlation is expected between digit span and all measures of speechreading ability for both the deaf and hearing groups.
- The strength of the correlation between digit span and performance on the TAS core subtests is predicted to increase as the memory load of the subtest increases (words<sentences<stories).
- A strong correlation is also predicted between digit span and performance on the focus subtest, since this makes comparatively heavy demands on memory.

9.1.iii Vocabulary

There are numerous studies demonstrating the impoverished spoken language vocabularies of deaf children in comparison to their hearing peers (e.g. Bishop 1983; Blamey 2003; Gregory & Mogford 1981; Lederberg & Everhart 1998; MacKay-Soroka & Trehub 1988; Spencer & Lederberg 1997; see section 2.20). The difference between deaf and hearing children's lexical development increases as they become older, and deaf children have been found to show little lexical development after the age of 12-13 years (Moeller et al. 1986). It is therefore unsurprising that deaf college students have been found to have more heterogeneous conceptual organisation than their hearing peers and weaker associations among lexical items (Marschark et al. 2004; McEvoy et al. 1999). Deaf individuals who are better readers, however, show patterns of association that are closer to those of their hearing peers (Marschark et al. 2004): this draws attention to the strong relationship between lexical knowledge and reading (e.g. Anderson & Freebody 1985; Geers & Moog 1989; LaSasso & Davey 1987; Moores et al. 1987; Paul & Gustafson 1991; Paul 2001; see section 2.24). DeVilliers and Pomerantz (1992) state that "many hearing-impaired students are caught in a vicious circle: their impoverished vocabularies limit their reading comprehension and poor reading strategies and skills limit their ability to acquire adequate vocabulary knowledge from context" (pg. 428). This could apply equally to speechreading as to reading. Additionally, however, new items of spoken vocabulary are usually encountered in a stream of speech. The ability to segment the speech stream is therefore likely to be important in vocabulary learning. Prosodic stress may be a particularly important cue in segmentation for deaf people (see sections 3.2.iii and 7.12.viii), and the ability to detect this may therefore facilitate vocabulary learning. The size and organisation of an individual's lexicon is, then, expected to be strongly related to their speechreading abilities.

Hypotheses:

- The hearing participants are expected to score better on an expressive English vocabulary test than the deaf participants.
- A positive correlation is expected between vocabulary score and speechreading performance on the TAS core subtests for the deaf group.

- Vocabulary score is expected to correlate with performance on the focus subtest for the deaf participants because the ability to detect prosodic stress is assumed to be important in segmenting the speech stream (see section 3.2.iii, and Chapter 7).

9.1.iv Phonological Awareness

Phonological awareness is a person's awareness of, access to, and ability to manipulate the phonology of their language at any sub-morphologic level, such as the syllable, onset, rime, and phoneme. It requires clearly differentiated phonological representations for lexical items, and for individual phonemes, in long-term memory (Burgess 2002). These representations are also necessary for phonological recoding in lexical access, phonetic recoding to maintain information in working memory, and retrieval of phonological codes from long-term memory (Gathercole et al. 1991; Wagner et al. 1994; Wagner et al. 1993; Wagner & Torgesen 1987; see section 3.8). Phonological coding and processing are therefore fundamental to audiovisual speech processing (see section 3.7), and assumed to hold a central role in speechreading (e.g. Rönnberg et al. 1998; see section 3.7.i). Poor phonological-lexical representations – that is, representations which are not fully segmented into phonemes, or which are not sufficiently distinct from their phonological neighbours to allow them to be quickly and reliably distinguished – and/or poor phonological processing skills are predicted to impact negatively on speechreading.

Evidence suggests that profound congenital deafness prevents the development of a robust, reliable inner speech code suitable for the phonological monitoring and processing of spoken language, and even intensive oral training does not equip most deaf people with a phonological code equivalent to that of hearing people (e.g. Campbell & Wright 1988; Hanson & MacGarr 1989; Miller 1997). It is not the case, however, that since deaf people cannot hear speech sounds they cannot develop a phonological code at all. A number of studies have shown that profoundly prelingually deaf children *can* develop a phonological code and perform phonological awareness tasks at an above chance level, but their performance is severely impaired in comparison to their hearing peers (Campbell & Wright 1988; Dyer et al. 2003; Hanson & Fowler 1987; Hanson & MacGarr 1989; Miller 1997). Deaf children make similar developmental phonological errors to those of younger hearing children (Dodd 1976; Oller & Kelly 1974; Vogel 1976; see section 2.21); they can write down speechread nonsense words (Dodd 1980); they are sensitive to rhyme as a salient

feature of lexical items in a memory task (Hermelin & O'Connor 1973); and they can perform phonological awareness tasks such as rhyme identification and homophone matching (Dodd & Hermelin 1977). In addition, they show evidence of using speechread information to perform phonological awareness tasks (Dodd & Hermelin 1977), suggesting that their phonological code was primarily derived from their perception of speech through speechreading (Dodd 1987). These studies were conducted with orally educated children, but as Parasnis and Whitaker (1992, reported in Parasnis 1998) showed, the use of a signed language does not preclude the development of a phonological code for processing text either. Some deaf signers make reliably correct rhyme judgements for orthographically dissimilar word pairs (this was found to be related to their English skills).

Hypotheses:

- The hearing group is predicted to outperform the deaf participants on all phonological awareness measures (rhyme, onset-vowel, phoneme, and the mean score)
- The deaf group is expected to perform comparatively well on the onset-vowel task, relative to the other phonological awareness tasks, since word onsets are particularly salient to deaf people (e.g. Sterne & Goswami 2000). The hearing participants are expected to perform best on the rhyme task, because the vowel is the most auditorially salient part of a word, and this task does not require the word's nucleus and coda to be segmented (this is developmentally more difficult than the onset-rhyme segmentation required for the rhyme task; see e.g. Ziegler & Goswami 2005). The phoneme task is expected to be the most difficult for both deaf and hearing participants because, although it requires onset-rhyme segmentation (rather than nucleus-coda), and focuses on the onset of the words, the vowel (which is auditorially salient, and comparatively easy to identify visually, see section 3.3.ii) must be ignored.
- A positive correlation is predicted between phonological awareness and speechreading performance on the TAS core subtests.
- Correlations are expected between the phonological awareness tasks and the corresponding TAS minimal pairs tasks: If speechreading was instrumental in the development of the deaf participants' phonological representations, then performance on the phonological awareness tasks may be expected to correlate

with performance on the minimal pairs items that focus on the corresponding part of the word. Performance on the phoneme task is therefore expected to correlate with performance on the word initial items; performance on the onset-vowel task with performance on the word medial and word initial items; and the rhyme task with the word final and word medial items.

9.1.v Summary of hypotheses and research questions

In summary, the hearing group are expected to out-perform the deaf participants on each of the spoken language related tasks (digit span, vocabulary, phonological awareness and reading age). A positive correlation is expected between each of the language-related measures (digit span, vocabulary, phonological awareness and reading age) and speechreading performance on the TAS core subtests, and inter-correlations are predicted between all of the language measures. Regression analyses will be conducted to investigate which of the measured variables explained variance in speechreading performance on the TAS, and to explore the relative predictive power of these variables.

The results for this chapter will be presented in two sections. The first will focus on the relative language skills of the groups of participants, and the second will explore the relationships between performance on the language-related tasks and on the speechreading tasks. The specific questions addressed are:

Section 1

1. How does the performance of the deaf and hearing participants compare on the four language measures?
2. Does the HoD group show superior language skills in comparison with the HoH group that may contribute to their superior speechreading performance?

Section 2

1. Is speechreading ability, as measured by the TAS core subtests, related to performance on the other language measures for the deaf participants?
2. Which factors explain individual differences in speechreading ability?
 - a. Do the language variables (phonological awareness, expressive vocabulary and reading age) account for a significant proportion of the variance in speechreading performance over and above that accounted for by
 - i. hearing aid use and language experience and preference?
 - ii. performance on the focus task?

- b. If so, what is the relative predictive power of phonological awareness and expressive vocabulary in explaining individual differences on the TAS core subtests?
3. What underlies the reading-speechreading relationship?
4. Correlations between the language variables and the core and additional TAS subtests: What are the roles of the language variables in speechreading?
5. Is speechreading ability related to performance on the other language measures for the hearing (HoH) participants?

The distribution of the data for each variable was analysed and transformed as necessary prior to these investigations (see Appendix M).

9.2 Method

9.2.i Procedure & Participants

Participants completed the tasks individually in a quiet room, in one or two sessions as part of the assessment battery. The phonological awareness and digit span tasks were presented on a laptop computer with a 15-inch screen. Appendix J describes the typical order in which the tasks were presented.

Some participants were not able to complete all tasks due to technological difficulties, time constraints or participant choice. In addition, the digit span task was introduced late into the testing battery, and therefore completed by comparatively few participants. Table 9.1 shows the number of participants who completed each task (see also Appendices G – I, which show the tasks completed by each participant).

Table 9.1: The number of participants who completed each language-related task

	Deaf	HoH	HoD
Reading Age	41	40	10
Phonological Awareness	41	39	10
Vocabulary	41	40	9
Digit span	21	9	7

9.2.ii Tasks

Working Memory

The ‘digits forward’ task is considered a reliable measure of the encoding, rehearsal, and storage processes involved in working memory (Engle 2000; Pisoni & Geers 2000; Rosen & Engle 1997). The digits forward span task from the British Ability

Scales, 2nd edition (BAS II, Elliott 1996) was adapted for use with both deaf and hearing participants. Rather than presenting lists of digits spoken live and asking the participants to repeat them, the digit sequences were presented visually on a laptop computer, and participants asked to write the digits down in order at the end of each sequence. The digits were presented at a rate of 2 digits per second (the rate recommended for oral presentation), that is, 300ms on-time and 200ms gap for each digit. Participants were instructed as follows:

'Press the space bar when you are ready. You will see a series of numbers on the screen. Watch them carefully and try to remember them. When you are asked to respond, write the numbers in the order that you saw them on the sheet provided. If the same number appears twice, write it twice. You can only see each number series once – they cannot be repeated.'

On the score sheet, the available stimuli were arranged in 'blocks' of items of the same number of digits. Items 1 to 5 consisted of two digits, 6 to 10, three digits, and so on, up to items 31 and 32 which consisted of 8 digits. Item 1 was administered first, and then the first item of each block (i.e. item 6, 11, 16, 21, 26, 31) until an item was failed or item 31 passed. When an item was failed, the remaining items in the previous block were administered in order. If more than one item in a block was failed, the previous block was administered, and this was continued until a block was completed with no more than one failure (this was the 'basal'). All the previously unadministered items in each subsequent block were then administered until a block was completed with no more than one pass, or until the end of the final item (32) was reached (this was the 'ceiling'). Each correctly recalled item (all digits recalled in the correct order) scored one point. The task yielded two measures of working memory: the raw score (the sum of the correct responses, with credit given for all the items below the basal), and the number of digits in the last block passed.

Vocabulary

The vocabulary test was adapted from the Boston Naming Test (Kaplan et al. 1983). The 60-item naming test was condensed to 30 items to reduce administration time and allow the removal of specifically North American items. Because the naming test becomes progressively difficult, one of each consecutive pair of items was selected (i.e. one out of items 1 and 2, one of items 3 and 4, one of 5 and 6, etc): where one of the pair was specifically North American (e.g. 'pretzel'), that item was excluded,

otherwise the selection was made on the basis of picture clarity. The 30 included items are listed on the score sheet (Appendix K). Participants were presented with a line drawing of each item and asked to give the English name for the object pictured, using speech, fingerspelling, or a combination of these. A correct response on an item scored 1, giving a maximum possible score of 30. Spelling errors were ignored where participants used fingerspelling, and responses scored as correct if they showed knowledge of the whole English word.

Phonological Awareness

Three PC-based phonological awareness tasks, developed by MacSweeney (MacSweeney & Goswami, in prep.) were administered to each participant; the tasks focus on the rhyme, onset and vowel, and initial phoneme of words respectively. They are picture-based, so participants were asked to name the pictures prior to testing to ensure that they associated each picture with the intended word. Where errors were made in pre-naming, the correct name was given (using the BSL sign and English word lip pattern for deaf BSL users, and fingerspelling the first letter of the word to prompt the name if that was unclear). After all the pictures needed for a task had been named, the trained ones were re-named. For each task, participants were asked to make button-press responses to indicate whether the specified part (rhyme, phoneme, or onset and vowel) of a pair of pictured words was the same or different. For the rhyme task, therefore, they were instructed (in their preferred language) to decide *‘whether two words sound the same at the end’*, for the phoneme task, *‘whether the very first sounds of the two words are the same’* and for the onset-vowel task, *‘whether both the first sound and the vowel that comes in the middle of the word are the same’*. Three demonstration items were used to explain each task, the participants were then presented with eight practice items before beginning the test items, which they were asked to go through as quickly as they could without guessing. There were 80 rhyme, 64 phoneme, and 88 onset-vowel items. The order of task presentation was counterbalanced. The percentage accuracy score was recorded for each task, and a mean phonological awareness score (the mean of the three task scores) calculated for each participant.

Reading

No available single reading test was suitable to test the reading of both the deaf and hearing respondents: they were either so difficult that they would be off-putting for

many deaf participants, or too easy to be discriminatory for the hearing participants. Two tests were therefore utilized: the Group Reading Test, 2nd edition, (GRT II) form D (The Macmillan Unit 2000), and the more difficult Vernon-Warden / Kirklees Reading Assessment Schedule (Vernon-Warden 1996, referred to below as the Kirklees). Both are cloze tests of reading comprehension that deliver a reading-age score. They were administered as recommended in their respective guidelines. In both, participants were instructed to read each sentence (in which one word was missing), and then select the word (from a closed choice) that best fitted in the gap. The GRT II was untimed, and participants were encouraged to complete as much as they could. Each correct answer scored one point, with a maximum possible raw score of 45. For the Kirklees, time was limited: participants were required to complete as much as they could in ten minutes. Again, each correct answer scored one point; the maximum possible raw score was 42. In addition, in this test wrong answers were penalised as marks were deducted to correct for guessing (1 point was subtracted if 5 to 10 items were wrong, 2 if 11 to 13, 3 if 14 to 17, 4 if 18 to 21, and 5 if there were 22 or more errors). Participants were therefore advised not to guess, but to try answer as many as they could. Participants whose reading was expected to be relatively poor (the majority of the deaf group) completed the GRT II first, and the Kirklees only if they scored 39 or above (equivalent to a reading age of 15;0+; the GRT II does not deliver specific reading ages for this upper end of scores). Those whose reading was expected to be relatively good (the majority of the hearing group) completed the Kirklees first, and the GRT II only if they scored 23 or less (equivalent to a reading age of below 15;0). The use of these two tests delivered a reading age of between 6;8 and 23;0 for each participant (see Appendix M, pg. 447-448, for an analysis of the relationship between the two tests, and for the raw scores and associated reading ages; Appendices H, G and I show the tasks completed by each participant).

9.3 Results Section 1

9.3.i How does the performance of the deaf and hearing participants compare on the four language-related measures?

The deaf group's performance on these tasks was compared with that of the hearing group with hearing parents (HoH) alone (with the exception of the digit span analysis,

see pg. 272), since the hearing participants' speechreading abilities differed as a function of hearing status (see section 6.8.i).

Table 9.2 summarises the deaf and hearing groups' performances on the spoken language-based tasks. These comparisons are described briefly, and illustrated in Figures 9.1 to 9.3.

Table 9.2: Comparison of the deaf and hearing participants' performance on the language tasks

		Deaf			Hearing			Significant difference?
		N	Mean	SD	N	Mean	SD	
RA (yrs;mths)		41	14;5	38.86	40	18;10	28.21	$p < .001$
Digit span	raw score	21	19.71	5.28	16	25.25	3.34	$p < .005$
	no. digits	21	5.43	1.21	16	6.50	0.73	$p < .02$
Vocab (raw score)		41	24.80	3.20	40	28.38	1.46	$p < .001$
PA	Mean (%)	41	75.36	8.91	39	90.10	6.88	$p < .001$
	Rhyme (%)	41	82.32	12.65	39	94.18	5.41	$p < .001$
	Onset-V (%)	41	79.29	7.30	39	88.18	10.10	$p < .001$
	Phoneme (%)	41	64.45	11.97	39	87.95	10.62	$p < .001$

Reading: As expected, the hearing participants demonstrated a significantly higher mean reading age than the deaf group ($t=6.87$, $d.f.=79$, $p < .001$; see Figure 9.1).

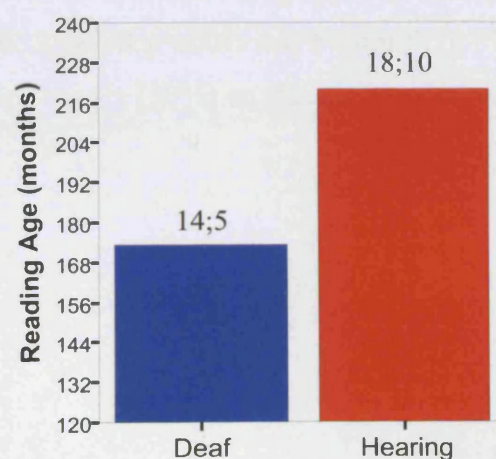


Figure 9.1: Mean reading ages for deaf and hearing participants (reading ages given above bars are in yrs;mths)

Digit Span: Twenty-one deaf participants (10 DoD, 9 hearing aid users), and sixteen hearing participants (7 HoD³³) completed the computer-based adaptation of the British Ability Scales digit span test. The hearing group significantly outperformed the deaf participants on this task (raw score³⁴: $U=71.5$, $p<.005$; number of digits recalled: $U=90.0$, $p<.02$; see Figure 9.2).

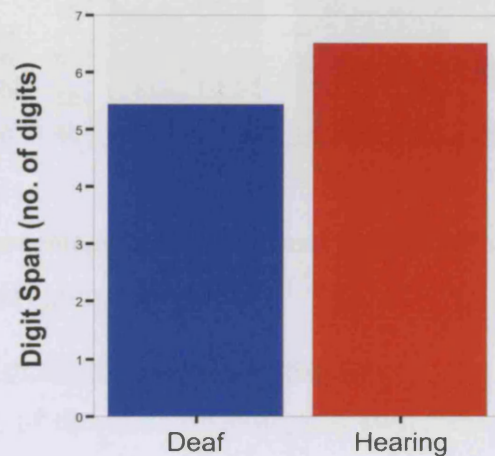


Figure 9.2: Performance on the digit span task by the deaf and hearing (HoH) groups

Vocabulary: As Figure 9.3 illustrates, the hearing groups' vocabulary scores were close to ceiling, and significantly higher than the deaf participants' ($U=254.5$, $p<.001$).

Phonological Awareness: The hearing group significantly outperformed the deaf participants ($U=165.0$, 2-tailed $p<.001$; see Figure 9.3). The deaf group performed significantly better than chance (50%) on this measure of phonological awareness.

³³ Due to the small number of hearing participants who completed the digit span task, the HoD participants were combined with the other hearing participants for this analysis. There was no difference in the respective digit spans of the HoH and HoD groups ($t=.705$, $df=14$, $p=.492$; see section 9.3.ii)

³⁴ Nonparametric statistics used because variances are not homogenous ($F=6.96$, $p<.02$).

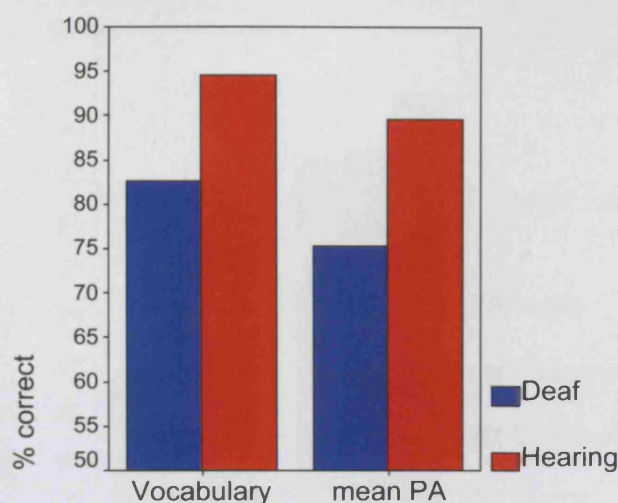


Figure 9.3: Mean percentage vocabulary and phonological awareness scores for the deaf and hearing (HoH) groups

Relative difficulty of phonological awareness tasks

It was predicted that, of the three phonological awareness tasks (rhyme, onset-vowel and phoneme), the deaf participants would show the highest performance on the onset-vowel task, since the beginning of a word is the most visually salient and least variant (see e.g. Gow et al. 1996). The hearing participants were expected to perform best on the rhyme task, because linguistically the rime is a particularly salient phonological unit, which may have an organising function in English phonology (Goswami 2000). The phoneme task was expected to be the most difficult for both deaf and hearing participants.

As Figure 9.4 shows, the order of difficulty across the tasks followed a similar pattern in each of the groups. They achieved the highest scores on the rhyme task, followed by the onset-vowel task, and finally, the phoneme task. However, the relative performance of the deaf group on the onset-vowel task did differ from that of the hearing groups. Wilcoxon signed rank tests showed no significant difference between performance on the onset-vowel and phoneme tasks for the hearing group (2-tailed $p=.527$), but the deaf group performed significantly better on the onset-vowel task (2-tailed $p<.001$). The deaf participants did, then, perform better on this task, in comparison to the other PA tasks, than the hearing participants.

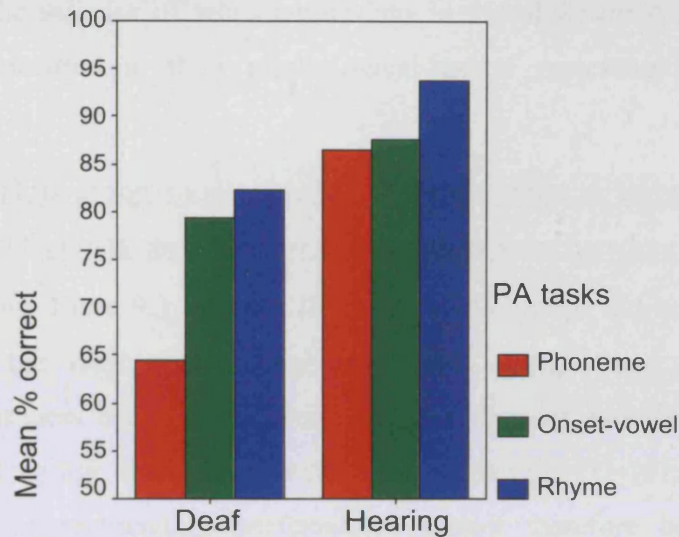


Figure 9.4: Performance on each of the phonological awareness tasks by the deaf and hearing (HoH) groups

Summary and discussion: As expected, the hearing participants significantly outperformed the deaf participants on each of the language tasks, although it should be noted that the group means mask a wide variation in the language skills of the individuals (see standard deviations in Table 9.2, pg. 271). The deaf group's superior speechreading performance cannot then be explained by unexpectedly good language skills. In fact, the difference of four-and-a-half years in reading age between the deaf and hearing participants is in line with the expected lag of approximately 5 years in reading level by the time deaf people leave school (see e.g. Allen 1986; Conrad 1979; DiFrancesca 1972; Trybus & Karchmer 1977).

Comparison of the mean scores on the three phonological awareness tasks showed that the order of difficulty across the tasks followed a similar pattern in each of the groups: they achieved the highest scores on the rhyme task, followed by the onset-vowel task, and finally, the phoneme task. The deaf group, however, scored better on the onset-vowel task in comparison to the other phonological awareness tasks than the hearing participants. Judging whether two words rhyme was expected to be the easiest task for the hearing participants since the rime is a very salient linguistic unit. That the deaf group found this task easiest as well may also reflect the linguistic properties of the rime. In addition, rhyming is taught explicitly to both deaf and hearing children, and emphasised from early childhood through language games and nursery rhymes. The deaf group's relative performance on the onset-vowel task is

likely to reflect the salience of word beginnings in visually perceived speech: these may be better specified in their phonological-lexical representations than word endings.

9.3.ii Does the HoD group show superior language skills in comparison with the HoH group that may contribute to their superior speechreading performance?

It can be seen from Table 9.3 that the HoH and HoD groups did not differ in their performance on the digit span, vocabulary (both groups were at ceiling), or phonological awareness tasks. In addition, those with deaf parents demonstrated a lower mean reading age than those with hearing parents ($U=101.5$, $p<.02$). The former's superior speechreading performance cannot therefore be explained by superior language skills in these individuals.

Table 9.3: Comparison of the HoH and HoD participants on the language measures

		HoH			HoD			Significant difference?
		N	Mean	SD	N	Mean	SD	
Digit span	raw score	9	25.78	3.23	7	24.57	3.60	NS ($t(14)=.705$, $p=.492$)
	no. digits	9	6.44	0.73	7	6.57	0.79	NS ($U=28.5$, $p=.712$)
Vocab (raw score)		40	28.38	1.46	9	28.33	1.12	NS ($U=165.5$, $p=.696$)
Mean PA (%)		39	90.10	6.88	10	86.30	9.80	NS ($t(47)=.1.21$, $p=.233$)
RA (yrs;mths)		40	18;10	28.21	10	16;2	39.69	Sig. difference ($U=101.5$, $p<.02$)

9.4 Results Section 2

9.4.i Is speechreading ability, as measured by the TAS core subtests, related to performance on the other language measures for the deaf participants?

The language measures were, unsurprisingly, inter-correlated. Table 9.4 shows a correlation matrix for the language-related measures tested (digit span, vocabulary, phonological awareness and reading), plus age, non-verbal IQ, risk-taking and impulsiveness, and the form and motion coherence thresholds.

Table 9.4: Intercorrelations between the language measures, and age, non-verbal IQ, risk-taking & impulsiveness, and motion and form coherence thresholds (**red** indicates significance at 2-tailed $p < .05$; **blue**, borderline significance at 1-tailed $p < .05$)

		Digit span	Vocabulary	Phonological Awareness	Reading Age
Vocabulary	r	.494			
	p	.023			
	N	21			
Phonological Awareness	r	.630	.540		
	p	.002	.000		
	N	21	41		
Reading Age	r	.498	.739	.581	
	p	.022	.000	.000	
	N	21	41	41	
Age	r	-.389	-.013	.020	-.077
	p	.081	.938	.900	.632
	N	21	41	41	41
Non-Verbal IQ	r	.221	.399	.147	.289
	p	.335	.010	.358	.067
	N	21	41	41	41
Risk-taking & Impulsiveness	r	.220	.449	.562	.584
	p	.351	.047	.010	.007
	N	20	20	20	20
Motion Coherence Threshold	r	-.291	-.246	-.229	-.363
	p	.201	.246	.282	.082
	N	21	24	24	24
Form Coherence Threshold	r	-.041	.010	-.059	-.207
	p	.859	.963	.783	.331
	N	21	24	24	24

Positive correlations were predicted between speechreading performance on the TAS and performance on each of the other language measures. These relationships are considered below in the light of the intercorrelations between measures.

Table 9.5: Correlations (2-tailed) between performance on the TAS core subtests and on the language measures, with partial correlations controlling for inter-related measures

Correlations with language measures		Partial correlations, controlling for...	
Digit span	$r(21) = .697, p < .001$	Age	$r(18) = .694, p < .002$
		Vocabulary	$r(18) = .570, p < .01$
		Phonological Awareness	$r(18) = .482, p < .05$
		Reading age	$r(18) = .576, p < .01$
Vocabulary	$r(41) = .649, p < .001$	Non-verbal IQ	$r(38) = .640, p < .001$
		Digit Span	$r(18) = .466, p < .05$
		Phonological Awareness	$r(38) = .518, p < .002$
		Reading age	$r(38) = .351, p < .05$
		Risk-taking & Impulsiveness	$r(17) = .616, p < .01$
Phonological Awareness	$r(41) = .506, p < .002$	Digit span	$r(18) = .397, p = .083$
		Vocabulary	$r(38) = .242, p = .132$
		Reading age	$r(38) = .221, p = .171$
		Risk-taking & Impulsiveness	$r(17) = .587, p < .01$
Reading age	$r(41) = .630, p < .001$	Non-verbal IQ	$r(38) = .614, p < .001$
		Digit span	$r(18) = .385, p = .094$
		Vocabulary	$r(38) = .294, p = .066$
		Phonological Awareness	$r(38) = .479, p < .005$
		Risk-taking & Impulsiveness	$r(17) = .644, p < .005$
		Motion Coherence Threshold	$r(21) = .538, p < .01$

It can be seen from Table 9.5 that each of the four language measures correlated significantly with speechreading (these correlations are illustrated in Figure 9.5). The correlations with digit span, expressive vocabulary and reading age survived controlling for each of the other related measures (although the partial correlations between speechreading performance and reading age were of borderline significance (1-tailed $p < .05$) when vocabulary or digit span were controlled for). The relationship between speechreading and phonological awareness was less robust. It did not survive controlling for vocabulary or reading age, and was of borderline significance (1-tailed $p < .05$) when digit span was controlled for.

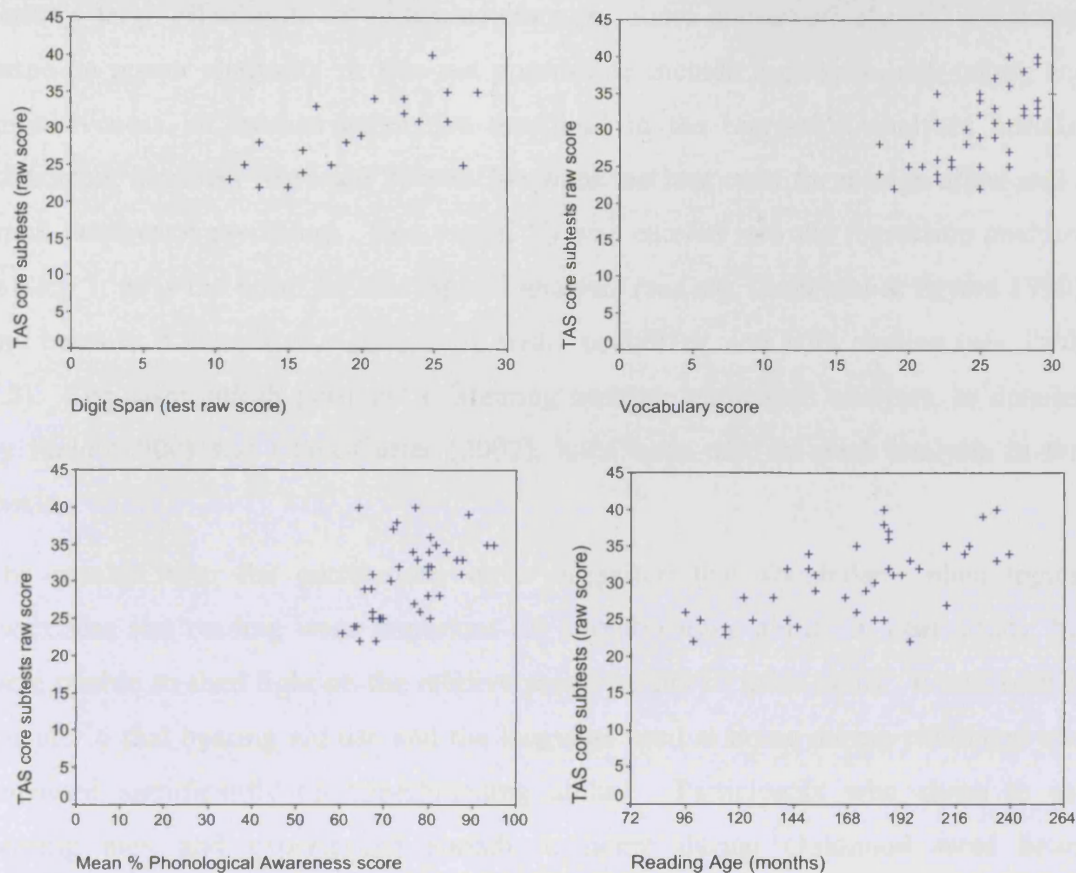


Figure 9.5: Scatterplots illustrating the relationships between the deaf participants' performance on the TAS and on the four other language measures assessed: digit span (top left), vocabulary (top right), phonological awareness (bottom left), and reading age (bottom right)

Summary: As predicted, each of the language measures assessed correlated significantly with speechreading performance on the TAS core subtests. The relationships with digit span and expressive vocabulary appear particularly robust: they do not simply reflect the relationships with other measures.

9.4.ii Which factors explain individual differences in speechreading ability?

Fixed-ordered multiple regression analyses were conducted to investigate which of the measured variables explained variance in speechreading performance on the TAS, and to explore the relative predictive power of these variables. The results further highlighted the patterns of relationships observed between the language variables in the correlations in this chapter. These analyses were constrained by sample size, and current conventions for sample and predictor ratios when conducting multiple regression analysis. Green (1991) proposed that a sample size of 41 is sufficient to

detect a large effect with up to 6 predictors (or, more conservatively, 4-5 predictors based on power analysis). It was not possible to include digit span, risk-taking and impulsiveness, or motion coherence threshold in the regression analyses because participant numbers (between 20 and 24) were too low even for a large effect and a small number of predictors. Non-verbal IQ was entered into the regression analyses in Step 1, as is the norm for this type of analysis (see e.g. Goswami & Bryant 1990), and because it correlated significantly with vocabulary, and with reading (see Table 9.5). The assumptions pertinent to running multiple regression analyses, as detailed by Field (2000) and Clark-Carter (2002), have been met for each analysis in this thesis.

The results from the correlations have suggested that vocabulary, phonological awareness and reading were important for speechreading ability in deaf adults, but were unable to shed light on the relative predictability of these skills. It was seen in Chapter 6 that hearing aid use and the language used at home during childhood also impacted significantly on speechreading ability. Participants who chose to use hearing aids and experienced speech at home during childhood were better speechreaders, and were also more likely to prefer to use English in their everyday communication. This raises the question of whether the relationships seen between the language variables and speechreading simply reflect these communication choices and experiences. In addition, it was seen in Chapter 7 that performance on the focus task was significantly correlated with speechreading performance on the TAS core subtests. The differences in meaning conveyed through focus in spoken English are conveyed by different means in BSL. The relationship seen between performance on the focus and TAS core subtests may therefore reflect knowledge of spoken language. Regression analyses were carried out to investigate the following questions:

- a) Do the language variables (phonological awareness, expressive vocabulary and reading age) account for a significant proportion of the variance in speechreading performance over and above that accounted for by hearing aid use and language experience and preference?
- b) Do the language variables and focus share the proportion of variance in performance on the TAS core subtests that they account for?

- c) What is the relative predictive power of phonological awareness and expressive vocabulary in explaining individual differences on the TAS core subtests?

Do the language variables (phonological awareness, expressive vocabulary and reading age) account for a significant proportion of the variance in speechreading performance over and above that accounted for by hearing aid use and language experience and preference?

As Table 9.6 shows, non-verbal IQ was entered in step 1, but did not explain a significant proportion of the variance in speechreading scores (just 3% of the variance in speechreading performance was accounted for by non-verbal IQ). Hearing aid use and childhood home language were entered together in step 2, and accounted for just over 33% of additional variance in speechreading performance. Phonological awareness, vocabulary and reading age, entered in step 3, together accounted for a further 32% of the variance. Each of these predictors represented a large effect on the speechreading scores. When the order in which the language and demographic variables were entered into the analysis was reversed, so that the language variables were entered in step 2, they accounted for nearly 46% of additional variance in speechreading scores. In this model, hearing aid use and childhood home language, entered in step 3, explained a further 20% of the variance. Again, each of these predictors represented a large effect on the speechreading scores. Between non-verbal IQ, hearing aid use, childhood home language, phonological awareness, expressive English vocabulary, and reading age, 69% of the variance in performance on the TAS core subtests could be explained.

Both the demographic variables (hearing aid use and childhood home language) and the language variables (phonological awareness, vocabulary and reading) were significant predictors of speechreading performance on the TAS core subtests. Little of the proportion of variance accounted for by the demographic variables was shared by the language variables: the significant contribution made by the language variables to the variance in speechreading performance was independent of hearing aid use and childhood home language, and vice versa.

Table 9.6: Summary of multiple regression analyses exploring the relative predictive power of hearing aid use and childhood home language, and phonological awareness, vocabulary and reading age in explaining individual differences on the TAS core subtests

Step	Independent Variable	TAS core subtests	
		R ²	R ² change
1	Non-verbal IQ	.033	.033
2	Hearing aid use & Childhood home language	.367	.334**
3	Vocabulary, Reading & Phonological awareness	.690	.323**
2	Vocabulary, Reading & Phonological awareness	.434	.458**
3	Hearing aid use & Childhood home language	.690	.199**

* $p < .05$, ** $p < .01$

It is also interesting to consider language preference in this context. It was seen in Chapter 6 that language preference did not have an effect on speechreading over and above that of either hearing aid use or childhood home language. It can be seen in Table 9.7 that it had a moderate effect on speechreading score when entered in step 2, accounting for nearly 14% of additional variance (after non-verbal IQ had been accounted for in step 1). However, it could not count for any significant additional variance after the language variables had been accounted for: when entered in step 3, after the language variables, it accounted for less than 1% of the variance in scores on the TAS core subtests.

Language preference is a significant predictor of speechreading ability, however, almost all of the variance in speechreading scores that it accounts for is explained by the language variables (and by hearing aid use and childhood home language, see Chapter 6). It does not contribute to the variance in speechreading performance over and above that explained by other variables.

Table 9.7: Summary of multiple regression analyses exploring the relative predictive power of language preference and the language variables (phonological awareness, vocabulary and reading) in explaining individual differences on the TAS core subtests

Step	Independent Variable	TAS core subtests	
		R ²	R ² change
1	Non-verbal IQ	.033	.033
2	Language Preference	.171	.138*
3	Vocabulary, Reading & Phonological awareness	.498	.327**
2	Vocabulary, Reading & Phonological awareness	.491	.458**
3	Language Preference	.498	.007

* $p < .05$, ** $p < .01$

Do the language variables and focus share the proportion of variance in performance on the TAS core subtests that they account for?

As Table 9.8 shows, non-verbal IQ was again entered in step 1, and did not explain a significant proportion of the variance in speechreading scores (40 participants, rather than 41, were included in this analysis since one participant did not complete the focus task; less than 2% of the variance in speechreading performance was accounted for by non-verbal IQ for these participants). When focus was entered in step 2, it accounted for 44% of additional variance in speechreading performance. Phonological awareness, vocabulary and reading age, entered in step 3, together accounted for a further 17% of the variance. Each of these predictors represented a large effect on the speechreading scores. When the order was reversed, so that the language variables were entered in step 2, they accounted for just over 45% of additional variance in speechreading scores. Focus, entered in step 3, then explained a further almost 16% of the variance. Again, each of these predictors represented a large effect on the speechreading scores. Between non-verbal IQ, focus, phonological awareness, expressive English vocabulary, and reading age, 63% of the variance in performance on the TAS core subtests could be explained.

Table 9.8: Summary of multiple regression analyses exploring the relative predictive power of hearing aid use and childhood home language, and phonological awareness, vocabulary and reading age in explaining individual differences on the TAS core subtests

Step	Independent Variable	TAS core subtests	
		R ²	R ² change
1	Non-verbal IQ	.018	.018
2	Focus	.458	.440**
3	Vocabulary, Reading & Phonological awareness	.628	.170**
2	Vocabulary, Reading & Phonological awareness	.472	.453**
3	Focus	.628	.157**

* $p < .05$, ** $p < .01$

Focus and the language variables (phonological awareness, vocabulary and reading) share little of the variance that they accounted for in TAS core subtest scores, and both were significant predictors of speechreading performance. The significant contribution made by the language variables to the variance in speechreading performance was largely independent of the ability to visually identify focus, and vice versa.

Inspection of the significance of the individual language variables as predictors of speechreading performance when they were entered in step 2 revealed that, while vocabulary made an independent contribution to the variance in speechreading ($t = 2.133$, $p < .05$), phonological awareness ($t = 0.941$, $p = .353$) and reading age ($t = 1.469$, $p = .150$) did not. The relative predictive power of vocabulary and phonological awareness was confirmed by entering them separately into regression analyses. The factors underlying the speechreading-reading relationship, which is of particular interest because of the importance of literacy (see section 2.24), are investigated further in section 9.4.iii.

What is the relative predictive power of phonological awareness and vocabulary in explaining individual differences on the TAS core subtests?

Again, non-verbal IQ was entered in step 1 (see Table 9.9). When phonological awareness was entered in step 2, it accounted for 23.5% of the variance in speechreading performance on the TAS core subtests (in addition to the 3% accounted for by non-verbal IQ). Vocabulary, entered in step 3, accounted for a further 19% of the variance. Both of these predictors represented a large effect on the speechreading scores. When the order was reversed, and vocabulary was entered in step 2, before phonological awareness, it accounted for almost 40% of additional variance. However phonological awareness could not account for any significant additional variance after vocabulary had been accounted for. Between non-verbal IQ, phonological awareness and vocabulary, 46% of the variance in performance on the TAS core subtests could be explained.

Table 9.9: Summary of multiple regression analyses exploring the relative predictive power of phonological awareness and vocabulary in explaining individual differences on the TAS core subtests

Step	Independent Variable	TAS core subtests	
		R ²	R ² change
1	Non-verbal IQ	.033	.033
2	Phonological awareness	.267	.235**
3	Vocabulary	.460	.193**
2	Vocabulary	.429	.396**
3	Phonological awareness	.460	.032

* $p < .05$, ** $p < .01$

Expressive English vocabulary and phonological awareness were both significant predictors of speechreading ability. However, they appeared to share the proportion of variance that they accounted for, and only vocabulary contributed significantly over and above that explained by the other variable. Vocabulary was the stronger predictor of performance on the TAS core subtests and was significant regardless of the position in which it was entered into the regression analyses, whereas phonological awareness was only a significant explanatory variable if entered before vocabulary.

Small participant numbers mean that it was not possible to enter digit span into regression analyses, however the correlation analyses shown in Table 9.5 (pg. 277) suggest that working memory span may also make an independent contribution to speechreading.

9.4.iii What underlies the reading-speechreading relationship?

The correlation analyses showed that speechreading and reading each correlated significantly with risk-taking and impulsiveness, motion coherence threshold, and each of the other language variables (digit span, vocabulary and phonological awareness). The speechreading-reading correlation survived controlling for each of these, although controlling for digit span or vocabulary resulted in a correlation of borderline significance (1-tailed $p < .05$; see Table 9.5, pg. 277). This suggests that none of these variables can explain the speechreading-reading relationship alone: they are all likely to play a part. The regression analyses described below were carried out to investigate the relative contributions of vocabulary and phonological awareness, and of the demographic variables identified as making independent contributions to the variance in speechreading (hearing aid use and childhood language). As mentioned previously, it was not possible to include risk-taking and impulsiveness, motion coherence threshold, or digit span in regression analyses because of low participant numbers for these variables. Further work is required with greater participant numbers (at least $N=31$, and preferably $N=41$ or more; Green 1991) to determine the relative roles of each of these. The correlation analyses suggest that digit span may be expected to account for a significant proportion of the variance in speechreading that is accounted for by reading. The inter-relationship between these three variables is in line with previous findings of significant relationships between working memory capacity and both speechreading (e.g. Lidestam et al. 1999) and reading (e.g. McCutchen & Perfetti 1982), and is likely to reflect the fundamental role of the phonological loop in both processes (see section 3.7.i). The significant correlation between reading and motion coherence threshold ($r(24) = -.363$, 1-tailed $p < .05$, see Table 9.5, pg. 277) is of particular note in the light of the relationship between motion coherence sensitivity and speechreading discussed in Chapter 8. Visual motion sensitivity (as measured with random dot kinatogram, RDK, stimuli) has previously been found to be related to reading ability in hearing adults with literacy difficulties and in children (see e.g. Hansen et al. 2001; Sperling et al. 2003;

Talcott et al. 2000; Talcott et al. 2002; Witton et al. 1998; see section 9.1.i.a). In addition, Samar and colleagues (2002) found Visual Evoked Potential (VEP) evidence that *deaf* adult poor readers, as a group, show magnocellular system deficits in comparison to deaf good readers. The finding here of a small but significant relationship between reading age and motion coherence threshold is, then, in line with previous findings. As discussed above (section 9.1.i.a), the contribution of the magnocellular system to reading is unlikely to lie in the discrimination of letter forms (these are best processed by parvocellular system components), but may play a role in the spatial localization of the letter strings on the page, and in the generation and control of eye movements (Cornelissen et al. 1998; Hansen et al. 2001; Stein & Walsh 1997).

Regression analyses investigating the relative contribution of hearing aid use, childhood home language, phonological awareness and expressive vocabulary to the speechreading-reading relationship: Each of these five predictor variables (hearing aid use, childhood home language, phonological awareness, expressive vocabulary and reading) was included in the analysis on page 281-282, and reading was not found to make an independent contribution to the variance in speechreading. This suggests that one or more of the other four variables can account for the speechreading-reading relationship. That is, the proportion of the variance in speechreading explained by reading is also explained by one or more of the other variables. The analyses described here investigated are summarised in Table 9.10. As in previous analyses, non-verbal IQ was entered in step 1 in each case, but did not explain a significant proportion of the variance in speechreading scores. The first analysis concerned hearing aid use, childhood home language and reading. The demographic variables were entered together in step 2, accounting for just over 33% of additional variance in speechreading performance. Reading age, entered in step 3, accounted for almost a further 27% of the variance. Each of these predictors represented a large effect on the speechreading scores. Between non-verbal IQ, hearing aid use, childhood home language and reading age, 63% of the variance in performance on the TAS core subtests could be explained, but the demographic variables (hearing aid use and childhood home language) did not explain the speechreading-reading relationship. Phonological awareness and reading (and non-verbal IQ) were included in the second analysis. As can be seen in Table 9.10, phonological awareness, entered in step 2,

accounted for 23.5% of additional variance, and reading age, entered in step 3, a further 16%. Again, both of these predictors represented a large effect on the speechreading scores: phonological awareness did not explain the speechreading-reading relationship.

Table 9.10: Summary of multiple regression analyses exploring the relative predictive power of reading age and the other language variables (phonological awareness and vocabulary) in explaining individual differences on the TAS core subtests

Step	Independent Variable	TAS core subtests	
		R ²	R ² change
1	Non-verbal IQ	.033	.033
2	Hearing aid use & Childhood home language	.367	.334**
3	Reading age	.634	.267**
2	Phonological awareness	.267	.235**
3	Reading age	.426	.159**
2	Vocabulary	.429	.396**
3	Reading age	.478	.050 ^(*)
2	Phonological Awareness & Vocabulary	.460	.427**
3	Reading age	.491	.031

^(*) $p=.069$, * $p<.05$, ** $p<.01$

Phonological awareness was replaced by vocabulary in the third analysis. This accounted for almost 40% of additional variance when entered in step 2. The additional variance accounted for by reading, entered in step 3, was reduced to just 5%; this represents a small effect of borderline significance (2-tailed $p=.069$) on the speechreading scores, and suggests that expressive English vocabulary accounts for the majority of the relationship found between reading and speechreading in these deaf adults. When vocabulary and phonological awareness were entered together in step 2, accounting for nearly 43% of additional variance in speechreading, the proportion of additional variance accounted for reading, entered in step 3, was further

reduced to a non-significant 3%. This suggests that the speechreading-reading relationship seen in these deaf adults can be explained by vocabulary knowledge and (to a lesser extent) phonological awareness skills.

9.4.iv Correlations between the language variables and the core and additional TAS subtests: What are the roles of the language variables in speechreading?

The analyses presented above indicated that, while each of the language variables tested correlated significantly with speechreading ability, vocabulary (and possibly digit span) is both the best predictor of speechreading performance, and the most important factor identified in the speechreading-reading relationship.

Investigating the relationships between performance on these variables and on the individual speechreading subtests enables further hypotheses regarding the role of these language variables in speechreading to be explored. Specifically:

- Digit span is assumed to reflect the functioning of the phonological loop in working memory. The strength of the correlation between digit span and performance on the TAS core subtests was therefore predicted to increase as the memory load of the subtest increased (words<sentences<stories). A strong correlation was also predicted for the focus subtest, since this makes comparatively heavy demands on memory.
- Vocabulary score was expected to correlate with performance on the focus subtest because the ability to detect prosodic stress is assumed to be important in segmenting the speech stream, which is fundamental to vocabulary learning (see sections 3.2.iii and 7.2.ii).
- Correlations were predicted between the phonological awareness tasks and the corresponding TAS minimal pairs tasks: If speechreading was instrumental in the development of the deaf participants' phonological representations (Dodd 1987; see sections 2.21 and 3.8), then performance on the phonological awareness tasks may be expected to correlate with performance on the minimal pairs items that focus on the corresponding part of the word. Performance on the phoneme task is therefore expected to correlate with performance on the word-initial items; performance on the onset-vowel task with performance on the word-medial and -initial items; and the rhyme task with the word-final and -medial items.

Table 9.11 shows the correlations between the language measures and each of the TAS core and additional subtests. It can be seen that vocabulary, phonological

awareness and reading were related to speechreading performance on the single words, although these correlations were not strong. All of the language measures correlated significantly with performance on the sentence and story subtests. Minimal pairs performance was related only to vocabulary, and focus to digit span, vocabulary and reading.

Table 9.11: Correlations between the TAS core and additional subtests and the additional language measures (**red**: sig at 2-tailed $p < .05$ level, **blue**: borderline significance, sig. at 1-tailed $p < .05$)

			Digit span	Vocabulary	Phon. Awareness	Reading Age
TAS core subtests	Words	rho	.060	.309	.291	.298
		<i>p</i>	.795	.050	.065	.058
		N	21	41	41	41
	Sentences	r	.651	.622	.498	.620
		<i>p</i>	.001	.000	.001	.000
		N	21	41	41	41
	Stories	rho	.549	.471	.387	.460
		<i>p</i>	.010	.002	.012	.002
		N	21	41	41	41
Minimal Pairs		r	.358	.320	.252	.158
		<i>p</i>	.111	.042	.112	.325
		N	21	41	41	41
Focus		r	.604	.543	.256	.434
		<i>p</i>	.004	.000	.111	.005
		N	21	40	40	40

Vocabulary: Only vocabulary correlated significantly with every measure of speechreading ability. This adds to the emerging picture that vocabulary knowledge is fundamental in speechreading.

Digit span: The pattern of correlations with digit span may reflect that, when a speechreading task is fairly easy (as the single word and minimal pair subtests were for the deaf participants), the demands on processing and storage are relatively light. Comparatively poor working memory may therefore be adequate, and greater efficiency and capacity have little impact on performance. The demands on working memory are greater, however, in the sentence, story, and focus subtests, and the individual's relative processing and storage efficiency and capacity do impact on performance on these tasks.

Reading: Reading appears to be related, not to the ability to distinguish between individual phonemes, but to the ability to process connected (sentence- or story-level) speech and to visually perceive spoken language prosody.

Phonological awareness: The correlation between phonological awareness score and speechreading performance was stronger for the sentence and story subtests than for the single words. This may indicate the use of knowledge of phonotactics in the segmentation of the speech signal (e.g. van der Lugt 2001; see section 3.2.iv). However, since the correlations do not survive controlling for vocabulary (sentences: $r=.242$, $d.f.=38$, $p=.132$; stories: $r=.128$, $d.f.=38$, $p=.431$), it seems more likely that it reflects only the importance of general language knowledge in speechreading.

The correlation between the combined phonological awareness score and speechreading performance on the minimal pairs subtest as a whole was not significant. However, as Table 9.12 shows, correlations were evident between the constituent parts of these tasks.

Table 9.12: Spearman's Rho correlations (1-tailed) between the Phonological Awareness subtests and the TAS Minimal Pairs items grouped by word position

	Minimal Pairs (WI)		Minimal Pairs (WM)		Minimal Pairs (WF)	
	rho	<i>p</i>	rho	<i>p</i>	rho	<i>p</i>
PA (phoneme)	.267	.046	.037	.409	.034	.417
PA (onset-vowel)	.118	.231	.326	.019	.061	.353
PA (rhyme)	.029	.429	.218	.086	.041	.400

It can be seen that the correlation between performance on the phoneme and word initial items was of borderline significance (significant at the 1-tailed .05 level), and a significant correlation was found between the onset-vowel task and the word-medial (vowel) items. There were no further significant correlations. This suggests a relationship between the minimal pair and phonological awareness tasks that focused on word beginnings. The correlation between the two variables when only the 'word beginning' subtests of each was included (WI and WM minimal pairs, and phoneme and onset-vowel PA) was significant ($r=.352$, $d.f.=41$, 2-tailed $p<.05$).

9.4.v Summary and discussion of sections 9.4.i to 9.4.iv

A number of the analyses presented in this chapter suggest that knowledge of English vocabulary is particularly important in speechreading in deaf British adults:

regression analyses showed that it accounted for a greater proportion of the variance in speechreading performance on the TAS core subtests than phonological awareness, reading age, or the demographic variables, hearing aid use, childhood home language and language preference. Similarly, vocabulary appears to account for a large part of the relationship between reading and speechreading. This is in line with previous studies showing a strong relationship between lexical knowledge and reading (e.g. Marschark et al. 2004; Paul 2001). Vocabulary was also the only measured variable to correlate significantly with every measure of speechreading skill. That lexical knowledge should hold such a central role in speechreading is not surprising. Speechreading constitutes a primary means of acquiring spoken vocabulary for deaf people, and, at the same time, their speechreading skills are limited by their vocabularies. Further, lexical (as opposed to than sub-lexical) processing is likely to be particularly important in visual speech perception because the sublexical, segmental information is under-specified: lexical effects have been found to be most robust when bottom-up mapping is underdetermined (Samuel, 1996). As discussed in Chapter 7, deaf adults may speechread at a whole-word level, without success resting on their knowledge of, or ability to identify, individual phonemes or visemes.

The correlation analyses also suggest the importance of working memory in speechreading. This is in agreement with previous studies that have identified it as fundamental (e.g. Lidestam et al. 1999; Rönnberg et al. 1999). Participant numbers were too small to include this variable in regression analyses (further work in this area is planned for the future), but the digit span – speechreading relationship survived controlling for vocabulary, suggesting that working memory may play a complementary role. Its pattern of correlations with the individual subtests suggests that it may be particularly crucial when processing demands are high. In the TAS, the demands on working memory are high enough for digit span to correlate with performance for the sentence, story and focus subtests. Given the segmentation requirements of everyday speechreading, and the additional difficulties presented by different talkers, switching rapidly between talkers (see the discussion in section 3.6, on normalization), and non-optimal viewing conditions (e.g. with the talker's face in shadow), for example, working memory capacity may be expected to be fundamental. Working memory capacity may also be important in the relationship between reading and speechreading. The finding that these two variables were significantly related for the deaf group included here confirms previous findings of a speechreading-reading

relationship for deaf adults (e.g. Bernstein et al. 1998a). Regression analyses suggest that vocabulary and (to a lesser extent) phonological awareness, can account for this relationship. It is interesting that, for these deaf adults, lexical knowledge appears to be more important than phonological knowledge both for speechreading and in the speechreading-reading relationship.

Turning now to phonological awareness and speechreading: speechreading is likely to have been instrumental in the development of deaf people's phonological representations because vision is the primary means by which deaf children perceive speech (see e.g. Dodd 1987). Phonological awareness, which requires clearly differentiated phonological representations for lexical items (Burgess 2002; see section 9.1.iv), would therefore be expected to correlate strongly with speechreading performance on a task focussing on phonological distinctions (like the minimal pairs task) in deaf children. However, the phonological representations of the deaf adults who participated in this study will also have been shaped by other factors, such as kinaesthetic articulatory feedback and, particularly, literacy. The phonological awareness abilities of these deaf adults may have been shaped more by literacy than by speechreading. The relationship between phonological awareness and reading (which remained significant when speechreading was controlled for: $r=.387$, $d.f.=38$, $p<.02$), is likely to be reciprocal (e.g. Perfetti et al. 1987), with each benefiting the other during development. Furthermore, there was no significant relationship between phonological awareness and minimal pairs performance (the significant correlation between performance on the TAS core subtests and phonological awareness appears to reflect only the interrelations between all of the language variables). There was, however, evidence of a relationship between the ability to discriminate speechread phonemes at the *beginning* of a word (the initial consonant and vowel – WI and WM minimal pairs) and phonological awareness about the beginnings of words. It was hidden in analyses looking at the combined minimal pairs and phonological awareness scores. However, when only the tasks focussing on the word onset and vowel were included (the WI and WM minimal pairs tasks and the phoneme and onset-vowel phonological awareness tasks), there was a significant relationship that survives controlling for reading age ($r=.331$, $d.f.=41$, 2-tailed $p<.05$). The beginnings of words (the initial consonant and vowel) have been described as “perceptual islands of reliability in normally reduced connected speech” (Gow et al 1996, pg. 66): they are the richest and least variant parts of words (see section 3.2.ii).

The visual perception of connected speech may thus offer relatively well-defined phonological information about the beginnings of words (at least in comparison to the rest of the word) for congenitally profoundly deaf people, and may play a greater role in the development of their phonological-lexical representations. Their representations of the rest of the word, on the other hand, may reflect speechreading less because the phonological information available through the visual perception of speech is less consistent (especially for word final information).

The group differences and correlations presented here and in previous chapters have been informative in suggesting variables that may be important in predicting speechreading skill. Chapter 10 will investigate whether these variables could reliably distinguish good from poor speechreaders, using *k*-cluster analyses, and will look in detail at the skills and characteristics of the highest- and lowest-scoring deaf speechreaders.

9.4.vi Is speechreading ability related to performance on the other language measures for the hearing (HoH) participants?

There was no evidence of a significant correlation between speechreading performance on the TAS and any of the additional language measures (see Table 9.13).

Table 9.13: Intercorrelations between the language measures for the hearing participants (**red**: sig at 2-tailed $p < .05$ level)

		Digit span	Vocabulary	PA	RA
TAS core subtests	<i>r</i>	.082	.163	.030	-.175
	<i>p</i>	.762	.315	.858	.279
	<i>n</i>	16	40	39	40
Digit span ³⁵	<i>r</i>		-.143	.378	.515
	<i>p</i>		.626	.164	.050
	<i>n</i>		14	15	15
Vocabulary	<i>r</i>			.175	.447
	<i>p</i>			.286	.004
	<i>n</i>			39	40
Phonological Awareness	<i>r</i>				-.229
	<i>p</i>				.161
	<i>n</i>				39

³⁵ The HoD group were included in these analyses due to small numbers for this variable (see pg. 272)

The null findings with respect to the relationships between language measures and speechreading ability for this group are in line with the findings of previous, early research reporting no significant correlations between speechreading and, for example, vocabulary or reading in hearing or postlingually hard-of-hearing adults (O'Neill 1951; O'Neill & Davidson 1956; Simmons 1959; Wong & Taaffe 1958). The findings suggest that the speechreading abilities of hearing adults are limited not by their English language knowledge and skills (which are extensive), but by their perceptual visual skills. Relationships between those skills and speechreading might be expected in groups of hearing adults who have poorer language skills. In other words, if language skills are less well developed they might be expected to limit speechreading abilities. Accordingly, the speechreading skills of adults diagnosed with dyslexia have been found to be poorer than those of non-dyslexic hearing adults, and to be related to reading, phonological awareness, and expressive vocabulary (Mohammed et al. 2006; and Appendix N). In this group, the speechreading-phonological awareness correlation was found to survive controlling for vocabulary, but not the other way round. This suggests that the deficit in speechreading in people with dyslexia may arise from a deficit in the adequacy of their speech-based (i.e. phonological) representations.

Summary

There was no evidence of a significant relationship between speechreading performance and any of the additional language measures for the hearing (HoH) participants. This is hypothesised to reflect the group's extensive English language knowledge and skills, which do not limit their speechreading abilities. These may instead be limited by their perceptual visual skills. That less extensive English language knowledge can limit speechreading skills in hearing people is supported by the significant correlations found in a group of adults diagnosed with dyslexia (Mohammed et al. 2006; and Appendix N).

Chapter 10

THE CHARACTERISTICS AND TASK PERFORMANCES OF THE BEST AND POOREST DEAF SPEECHREADERS

10.1 Introduction

The previous chapters have focussed on group performances, and have investigated the demographic characteristics associated with speechreading performance (Chapter 6), the relationship between low-level visual skills and speechreading (Chapter 8), and the language correlates of speechreading (Chapter 9). These chapters have indicated that the following characteristics are associated with better speechreading performance on the TAS core subtests in deaf adults:

- *Hearing aid use, language preference and experience, and type of schooling:* those who chose to wear aids, used some English (spoken or SSE) in their daily lives, grew up with spoken English being used in the home, and attended a selective oral grammar school showed superior performance.
- *Risk-taking and impulsiveness:* those who were more risk-taking and impulsive showed superior performance.
- *Identification of phonemes in meaningful contexts:* those who were better at identifying which of a minimal pair was spoken (through speechreading) showed superior performance of borderline significance.
- *Visual perception of prosody:* those who were better at identifying the focus in a speechread sentence showed superior performance.
- *Detection of coherent motion:* those with lower motion coherence thresholds showed superior performance.
- *English language skills and working memory:* those with good language skills, as measured by digit span (use of the phonological loop in working memory), expressive vocabulary, phonological awareness and reading, showed superior performance.

This chapter consists of two parts, both with the general aim of further investigating the characteristics and task performances of the highest- and lowest-scoring deaf speechreaders. In the first part, the results of *k*-means cluster analyses will be reported to see whether each of the scale variables identified in earlier chapters as

predicting speechreading performance on the TAS core subtests could reliably distinguish good from poor speechreaders. Cluster analyses of this kind are appropriate when the number of groups is small and known a priori (Beauchaine & Beauchaine 2002), and have been used for a similar purpose by Harris and Moreno (2006).

The second part will focus on individual performances through a multiple case study design to investigate whether the results of the group analyses are reflected in the performances of individuals. The patterns of strengths and weaknesses in the highest- and lowest-scoring deaf speechreaders will be analysed to assess the extent to which good and poor speechreaders respectively have similar profiles, and the extent to which the factors associated with good/poor speechreading are seen consistently in these individuals. The characteristics and task performances of ten of the deaf participants will be considered in detail: those who achieved the five highest and the five lowest scores on the TAS core subtests.

10.2 *k*-cluster analyses

Nineteen of the deaf participants were included in these analyses: the nine who scored above 34 on the TAS core subtests (the good speechreaders: TAS Group 1; range of scores: 78-89%), and the ten who scored below 26 (the poor speechreaders: TAS Group 2; range of scores: 49-56%). *k*-means cluster analyses using two clusters (group 1 = better performance, group 2 = poorer performance) were performed on the eight scale variables identified in earlier chapters as being related to speechreading performance on the TAS core subtests to see whether they reliably distinguished the good and poor speechreaders. The measures included were risk-taking & impulsiveness (see Chapter 6), minimal pairs and focus (Chapter 7), motion coherence threshold (Chapter 8), and vocabulary, phonological awareness, digit span and reading age (Chapter 9). The results of these analyses are summarised in Table 10.1. The variables are arranged in order of the reliability with which they distinguished the good (TAS Group 1) and poor (TAS Group 2) speechreaders. It can be seen that no variable distinguished the good from poor speechreaders perfectly: Group 1 of each variable contained at least one poor speechreader as well as good speechreaders.

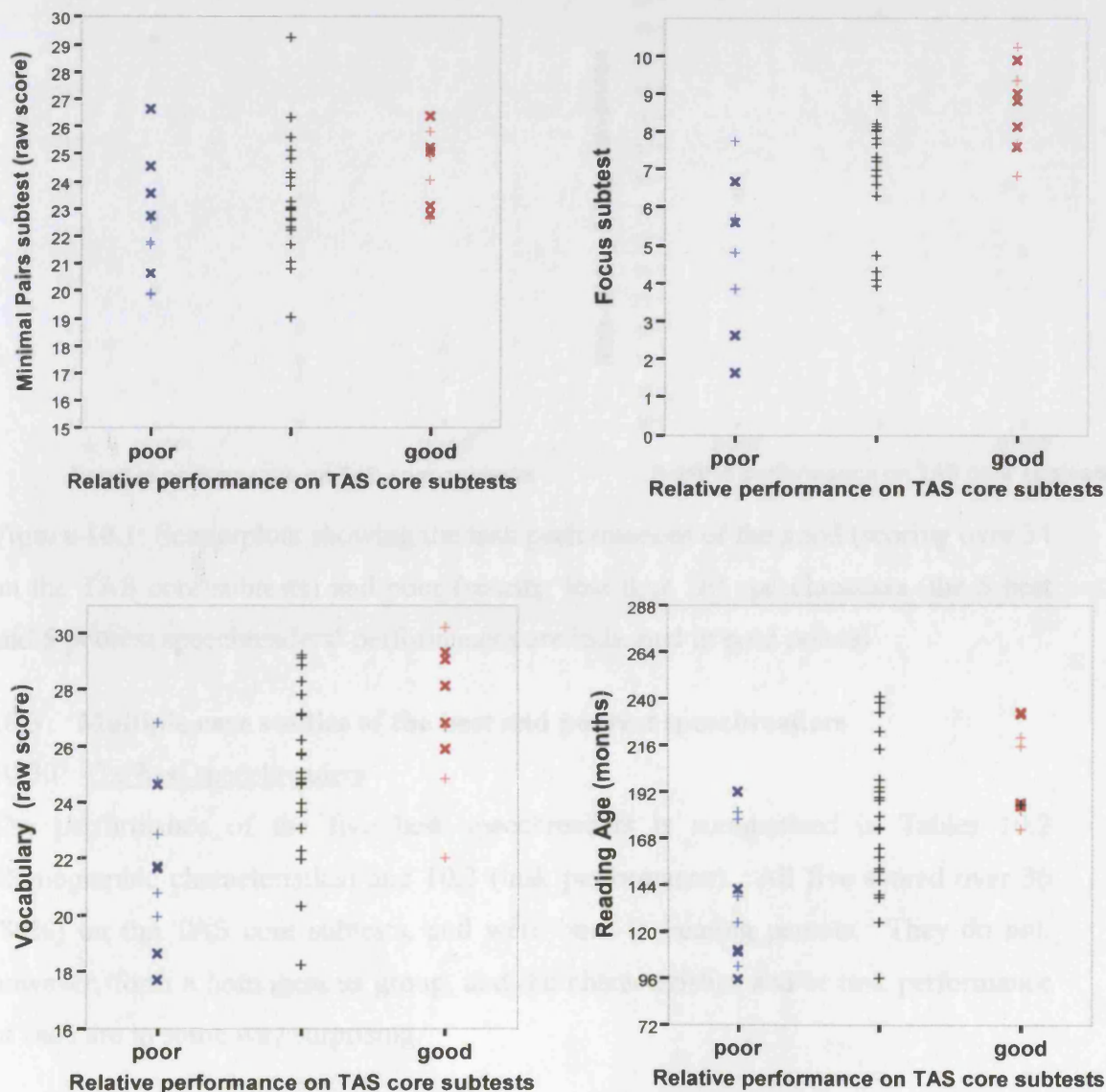
Table 10.1: Summary of results of cluster analyses

Variable:	Variable Group 1			Variable Group 2		
	<i>Cluster centre</i>	TAS Group (N)		<i>Cluster centre</i>	TAS Group (N)	
		1	2		2	1
Digit span	27	3	1	14	6	0
Focus	8	9	2	5	7	0
Reading age	197	9	3	121	7	0
Expressive vocabulary	27	8	3	21	7	1
Minimal pairs	25	6	3	22	7	3
Phonological Awareness	86.83	5	1	67.99	9	4
Risk-taking & impulsiveness	34.5	2	3	25.1	1	3
Motion Coherence Threshold	11.37	3	7	23.15	1	1

For digit span, focus, and reading age all of the participants assigned to Group 2 (those showing poorer performance) were poorer speechreaders (TAS Group 2), and the majority (75-82%) of those assigned to Group 1 (those showing better performance) were good speechreaders (TAS Group 1). This further highlights the importance of these factors in speechreading, and suggests that digit span, which could not be included in regression analyses because of low participant numbers, may be an important predictor of speechreading ability. Expressive vocabulary, which was identified in Chapter 9 as playing a particularly important role in speechreading, also discriminated well between the good and poor speechreaders: 8 of the 11 participants assigned to Group 1 were good speechreaders, and 7 of the 8 assigned to Group 2 were poor speechreaders. The majority of the participants assigned to the minimal pairs Groups 1 and 2 were good and poor speechreaders respectively, but they were not distinguished as reliably using this measure as with the aforementioned variables. The distribution of good and poor speechreaders in the phonological awareness clusters suggests that poor speechreading is associated with poor phonological awareness (9 of the 10 poor speechreaders were assigned to Group 2 for phonological awareness), but good speechreading can be associated with either good or poor phonological awareness (5 good speechreaders were assigned to Group 1, but 4 to Group 2). Phonological awareness therefore distinguished between the good and poor speechreaders less well than the other language variables. This supports the finding

of a significant, but not robust, correlation between speechreading and phonological awareness seen in Chapter 9. Risk-taking & impulsiveness, and motion coherence threshold did not distinguish reliably between the good and poor speechreaders. This suggests that, although these variables were associated significantly with speechreading performance at a group level (see the scatterplots illustrating these correlations: Figure 6.17, pg. 197, and Figure 8.9, pg. 255, respectively), individuals can be good speechreaders and less risk-taking and impulsive or sensitive to motion, or vice versa.

The relative performances of the better and poorer speechreaders are illustrated in Figure 10.1, which also indicates the five best and poorest speechreaders' task performances, discussed in section 10.3.



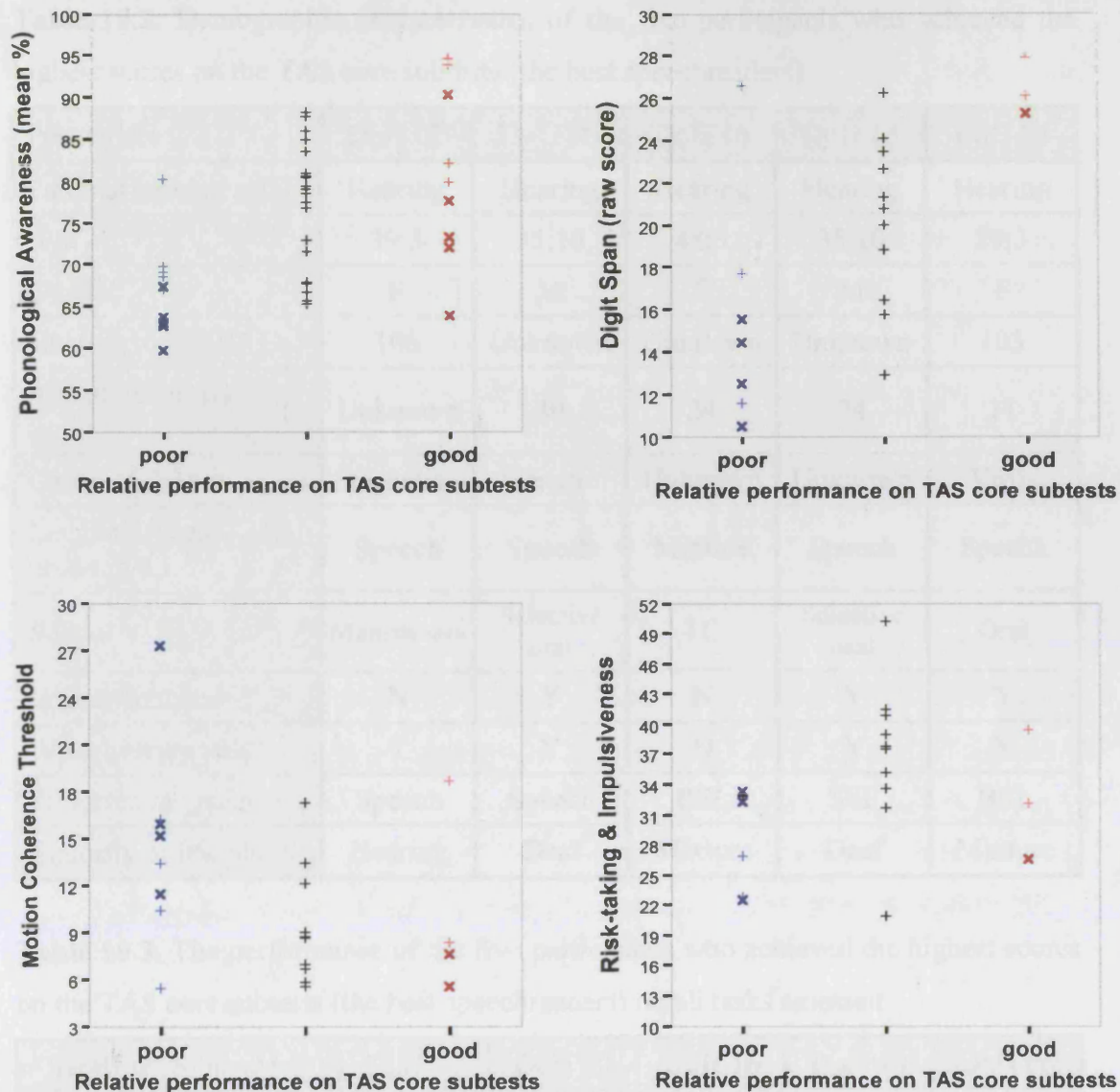


Figure 10.1: Scatterplots showing the task performances of the good (scoring over 34 on the TAS core subtests) and poor (scoring less than 26) speechreaders (the 5 best and 5 poorest speechreaders' performances are indicated in bold points)

10.3 Multiple case studies of the best and poorest speechreaders

10.3.i The best speechreaders

The performance of the five best speechreaders is summarised in Tables 10.2 (demographic characteristics) and 10.3 (task performance). All five scored over 36 (80%) on the TAS core subtests, and were born to hearing parents. They do not, however, form a homogenous group, and the characteristics and/or task performance of each are in some way surprising.

Table 10.2: Demographic characteristics of the five participants who achieved the highest scores on the TAS core subtests (the best speechreaders)

Participant	DoH 02	DoH 20	DoH 16	DoH 13	DoH 06
Parental hearing status	Hearing	Hearing	Hearing	Hearing	Hearing
Age	39;3	35;10	48;3	35;10	29;3
Gender	F	M	F	M	F
Hearing loss (dB)	106	Unknown	Unknown	Unknown	103
Age at diagnosis (mths)	Unknown	30	24	24	11
Cause of deafness	Genetic	Genetic	Unknown	Unknown	Virus
Language used growing up	Speech	Speech	Mixture	Speech	Speech
School	Mainstream	Selective oral	TC	Selective oral	Oral
Higher education?	N	Y	N	Y	Y
Wear hearing aids?	Y	Y	N	Y	Y
Preferred language	Speech	Speech	BSL	SSE	BSL
Majority of friends	Hearing	Deaf	Mixture	Deaf	Mixture

Table 10.3: The performance of the five participants who achieved the highest scores on the TAS core subtests (the best speechreaders) on all tasks assessed

'Best' speechreaders:		DoH 02		DoH 20		DoH 16		DoH 13		DoH 06	
	N	score	rank	score	rank	score	rank	score	rank	score	rank
TAS core subtests (%)	41	89	[1]	89	[1]	87	[3]	84	[4]	82	[5]
TAS minimal pairs (%)	41	83	[7]	77	[18]	87	[3]	77	[18]	83	[7]
TAS focus (%)	40	90	[3]	90	[3]	80	[9]	100	[1]	80	[9]
NVIQ (%ile)	41	84	[24]	95	[5]	91	[16]	95	[5]	91	[16]
Risk & Impulsiveness	20	26.5	[17]	--	--	--	--	--	--	--	--
Digit span (raw)	21	25	[5]	--	--	--	--	--	--	--	--
Vocabulary (%)	41	97	[2]	90	[10]	97	[2]	93	[7]	87	[15]
Phon. Awareness (%)	41	77	[19]	64	[38]	89	[3]	73	[23]	72	[24]
Reading Age (yrs;mths)	41	15;4	[18]	19;6	[2]	19;0	[5]	15;4	[18]	15;6	[15]
Motion CT	24	7.9	[9]	6.1	[4]	--	--	--	--	--	--
Form CT	24	17.9	[5]	12.3	[17]	--	--	--	--	--	--

DoH 02 could be classified as oral: her friends are all hearing, and she chooses to wear hearing aids and prefers to communicate through speech. She also grew up using speech and went to a mainstream school. She scored well on the minimal pairs and focus subtests, as well as achieving the highest score on the TAS core subtests (41/45, 89%). She also achieved high scores (in the 1st quartile) on the vocabulary, digit span and form coherence detection tasks. Her scores on the motion coherence detection, reading and phonological awareness tasks were close to the median. She was the only one of the five best speechreaders to complete the risk-taking and impulsiveness questionnaire, and she scored surprisingly low on this measure, indicating a relatively controlled, cautious personality. Her low risk-taking & impulsiveness score and high speechreading score rendered her an outlier in the analysis of the relationship between these two variables, which were otherwise significantly correlated (higher risk-taking and impulsiveness scores, indicating a relatively more impulsive risk-taking personality, were associated with better speechreading performance; see section 6.8.iii.d). Risk-taking & impulsiveness is a composite score, and DoH 02 scored relatively low on risk-taking (DoH 02's score: 14.0; mean: 16.0; range for deaf participants: 9.5 – 21.5) and particularly low on impulsiveness (DoH 02's score: 12.5; mean: 17.8; range for deaf participants: 10.5 – 28.0; see Figure 10.2).

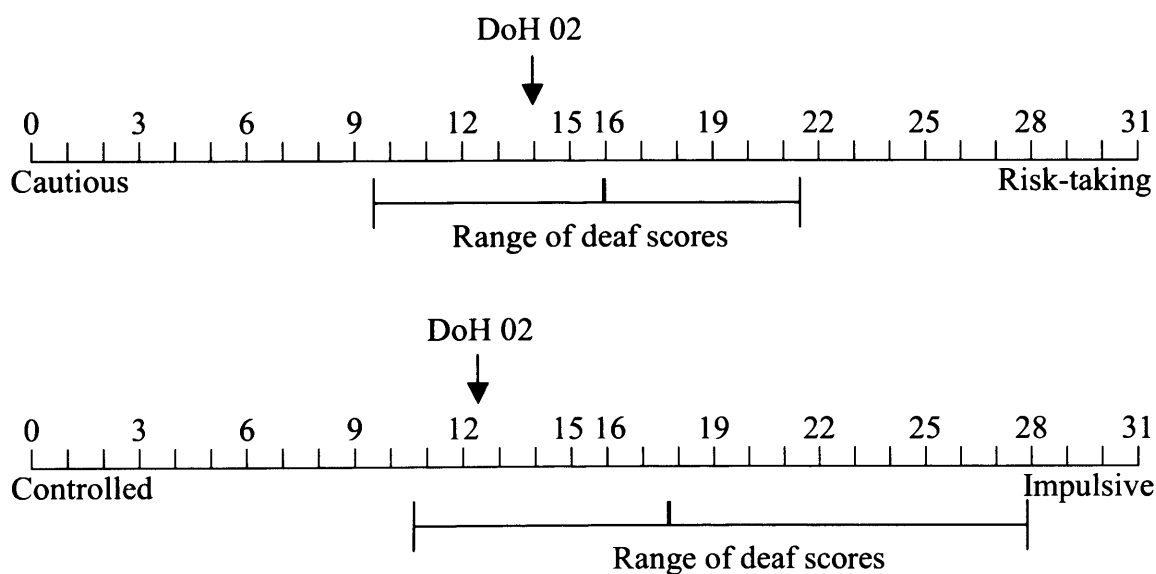


Figure 10.2: Illustrations of the DoH 02's risk-taking (top scale) and impulsiveness (bottom scale) scores, and the scores of the rest of the deaf group (means indicated by red lines)

The other participant who achieved the highest score on the TAS core subtests, DoH 20, could also be classified as oral, although the majority of his friends are deaf. He chooses to wear hearing aids, prefers to communicate through speech, went to an oral school and grew up using speech. He achieved high scores (in the 1st quartile) on the focus subtest, and on the vocabulary, reading and motion coherence detection tasks. However, he scored poorly on the phonological awareness tasks. His score on the form coherence detection was close to the median.

Unlike DoH 02 and DoH 20, DoH 16, who achieved the next highest score on the TAS core subtests, could not be classified as oral. She grew up using a mixture of spoken and signed language, was educated using Total Communication, and now chooses not to wear hearing aids and to communicate in BSL. She achieved consistently high scores on all of the tasks she completed: she was amongst the five highest scorers on the vocabulary, phonological awareness and reading tasks, and on the minimal pairs subtest, and in the 1st quartile on the focus subtest.

DoH 13 and DoH 06 show similar patterns in their characteristics and performance: Like DoH 16, they prefer to communicate manually: the former using sign supported English (SSE), and the latter BSL, although unlike her, they grew up using speech, attended oral schools and, as adults, choose to wear hearing aids. They both scored in the first quartile on the focus subtest and the vocabulary task.

The relative task performances of these five good speechreaders on variables found to be associated with speechreading are summarised in Table 10.4. All of these participants scored in the top quartile on the focus task. They also all scored well (in the 1st or 2nd quartile) on the vocabulary, reading, minimal pairs, and (for the 2 who completed it) motion coherence tasks. Their scores were more varied, however, on the phonological awareness tasks.

Table 10.4: Summary of task performance for the five best speechreaders

	DoH 02	DoH 20	DoH16	DoH13	DoH06
Good (1 st quartile)	Min pairs Focus Digit span Vocabulary	Focus Vocabulary Reading Motion CT	Min pairs Focus Vocabulary PA Reading	Focus Vocabulary	Min pairs Focus
Average (2 nd or 3 rd quartile)	PA Reading Motion CT	Min pairs		Min pairs PA Reading	Vocabulary PA Reading
Poor (4 th quartile)	Risk & Imp	PA			

10.3.ii The poorest speechreaders

The five poorest speechreaders (who scored less than 25 (56%) on the TAS core subtests) also form a heterogeneous group (see Tables 10.5 and 10.6).

Table 10.5: Demographic characteristics of the five participants who achieved the lowest scores on the TAS core subtests (the poorest speechreaders)

Participant	DoH 08	DoD 17	DoH 01	DoD 08	DoH 05
Age	30;1	56;11	40;2	33;10	35;9
Gender	F	M	M	M	F
Hearing loss (dB)	104	Unknown	98	100	Unknown
Age at diagnosis (mths)	18	6	Unknown	0	Unknown
Cause of deafness	Genetic	Genetic	Rubella	Genetic	Genetic
Language used growing up	BSL	BSL	Speech	BSL	Mixture
School	Oral	Oral	TC	TC	Oral
Higher education?	Y	N	N	Y	N
Wear hearing aids?	Y	N	N	N	N
Preferred language	BSL	BSL	BSL	BSL	BSL
Majority of friends	Deaf	Deaf	Deaf	Deaf	Deaf

All of these participants prefer to use BSL in their everyday communication, which is perhaps unsurprising given their poor speechreading skills. For each of the other

demographic variables, the *majority* fall into the category expected from the group analyses, but, as for the best speechreaders, there are exceptions. DoH 08, for example, was educated orally, attended higher education, and chooses to wear hearing aids, and DoH 01 grew up using speech at home. It is notable however, in Table 10.6, that none of these poor speechreaders achieved scores in the 1st quartile on any of the language measures.

Table 10.6: The performance of the five participants who achieved the lowest scores on the TAS core subtests (the poorest speechreaders) on all tasks assessed

'Worst' speechreaders:		DoH 08		DoD 17		DoH 01		DoD 08		DoH 05	
	N	score	rank	score	rank	score	rank	score	rank	score	rank
TAS core subtests (%)	41	49	[40]	49	[40]	51	[39]	53	[37]	53	[37]
TAS minimal pairs (%)	41	83	[7]	80	[13]	77	[18]	90	[2]	70	[36]
TAS focus (%)	40	60	[29]	20	[40]	30	[39]	70	[22]	--	--
NVIQ (%ile)	41	75	[30]	99	[2]	84	[24]	75	[30]	37	[39]
Risk & Impulsiveness	20	34	[9]	--	--	23.5	[18]	33	[12]	--	--
Digit span (raw)	21	15	[17]	13	[18]	11	[21]	16	[15]	--	--
Vocabulary (%)	41	63	[39]	83	[19]	73	[31]	73	[31]	60	[40]
Phon. Awareness (%)	41	65	[37]	68	[29]	61	[41]	63	[40]	64	[39]
Reading Age (yrs;mths)	41	8;4	[40]	16;4	[11]	9;6	[37]	9;6	[37]	12;2	[31]
Motion CT	24	15.8	[19]	12.1	[15]	16.6	[21]	27.7	[24]	--	--
Form CT	24	13.2	[7]	16.7	[13]	22.6	[24]	19	[19]	--	--

10.4 Summary

The *k*-means cluster analyses and multiple case study results presented here both confirm and extend the findings of the previous chapters. The participants who achieved the highest speechreading scores all showed good vocabulary, working memory and reading skills, and also performed well on the focus task. Their performance on the phonological awareness and minimal pairs tasks, and particularly on the motion coherence sensitivity and risk-taking & impulsiveness measures, were more variable.

The skills and characteristics of the five individuals who scored highest on the TAS core subtests, and those of the five who scored lowest, also illustrate the diversity of good and poor deaf speechreaders. They demonstrate that while language and

lifestyle choices and experiences, personality traits, and spoken language abilities are associated with good speechreading, they are not all necessary in an individual for them to become an excellent speechreader.

Chapter 11

SUMMARY AND CONCLUSIONS:

WHAT MAKES A GOOD ADULT SPEECHREADER?

11.1 Introduction

The primary aims of the research described in this thesis were:

- (a) To develop a speechreading test that assessed speechreading across several linguistic levels and was suitable for use with deaf and hearing adults
- (b) To use this new test to investigate speechreading in congenitally, profoundly deaf British adults and, specifically, to address the series of research questions outlined in Chapter 1 (section 1.6).

This chapter consists of two sections that reflect these two broad aims: The first (Section A) will consider the strengths, limitations, and future directions of the Test of Adult Speechreading (TAS). The second (Section B) will summarise the principal findings from the thesis, and then explore the theoretical implications of these. Finally, the limitations of this research will be considered, and potential future research directions proposed.

Section A: The Test of Adult Speechreading (TAS)

The first question posed in Chapter 1 concerned the Test of Adult Speechreading (TAS):

What should a test of speechreading in deaf and hearing adults comprise? Is the newly developed Test of Adult Speechreading (TAS) a reliable, valid, discriminatory and sensitive assessment of speechreading in deaf and hearing British adults?

It was decided in Chapter 4 (Section A) that the TAS should be a fifteen to twenty minute test, consisting of single words, sentences, and short stories. These were spoken by two talkers, and presented silently in a head and shoulders view on a laptop computer. Responses were made through closed choice picture pointing. The test development decisions made were summarized in more detail in section 4.7.

The TAS's reliability, validity, and usefulness are addressed in the sections that follow.

11.2 Strengths of the TAS

The validity of any investigation of speechreading is dependent on the assessment used and its suitability for the population of interest. The TAS was designed to be particularly appropriate for use with d/Deaf as well as hearing individuals. Deaf people, many of whom are bilingual in English and British Sign Language, can show marked differences from hearing people in their English vocabulary and syntactic skills (Bishop 1983; Blamey 2003; Wilbur 2000; see Chapter 2, Section E, and Chapter 9). The use of simple vocabulary and syntax familiar to Deaf adults in the TAS ensured that Deaf participants were not disadvantaged. The response mode, using picture choices only, similarly ensured that no advantages would accrue to fluent users of written or spoken English (predominantly hearing people). That is, the test was designed to be sensitive to the *perceptual* abilities that may underlie efficient speechreading, while holding the linguistic requirements at an appropriate level.

The TAS's reliability (Cronbach's alpha, inter-talker reliability, and test-retest reliability) and validity (concurrent, content, response, face and construct validity) were investigated directly in Chapters 4 and 5 (sections 4.10, 5.6 and 5.7). These were found to be acceptably high. The replication of consistent findings from previous literature is also evidence of the test's validity and sensitivity. For example, performance was better on spondees than on monosyllables in the single words subtest (see section 5.9.i, and e.g. Erber 1971). In the story subtest, performance decreased as utterance length (in number of words) increased (see 5.9.iii, and e.g. Boothroyd 1988). There was also a significant relationship between speechreading and the other spoken language measures for the deaf participants (see Chapter 9, and e.g. Bernstein et al. 1998a; Lidestam et al. 1999), and a positive, non-significant correlation with non-verbal IQ (see section 6.8.iii.c, and e.g. Jeffers & Barley 1971).

Since its development, there has been an ongoing demand for the TAS. It is currently being used in a variety of contexts, for example as a behavioural variable in fMRI studies (e.g. Capek et al. 2007). This work provides further evidence of the validity of the test with respect to brain imaging and the specific brain regions associated with speechreading. Capek and colleagues (2007) found that speechreading performance on the TAS correlated with activation in a very restricted part of the left superior temporal lobe (in deaf and hearing people). This same region can be shown to be specifically engaged when hearing people speechread (Calvert et al. 1997) and when

they are presented with audiovisual (compared with unimodal) speech (Calvert et al. 2000).

The TAS is also currently being used in a case study of an adult with speech processing impairments by Dr Chris Donlan and colleagues, University College London, and clinically by Speech and Language Therapists with older deaf children in secondary schools in the London area. In addition, the single words subtest alone has been used clinically with younger children, and the sentence subtest is being converted for use in the USA by Prof. Daphne Bavelier and colleagues, Rochester University. This demand for, and ongoing use of the TAS is testament to the need for a test of this type that assesses speechreading across a range of linguistic levels and is suitable for use with deaf testees. Feedback from users of the test has been positive, and suggests that they are happy that it achieves its purpose and is a valid, useable measure of speechreading.

11.3 Limitations and Future Directions for the TAS

The TAS is a useful assessment of speechreading at varying linguistic levels. However, no speechreading assessment can assess every aspect of speechreading in a controlled manner, and the choices made in test development (see Chapter 4) therefore resulted in some limitations. The following sections describe the current limitations and future directions of the TAS. An advantage of the digital format is that additions to the TAS assessment battery can be made relatively easily, and it is hoped that much of this work will be completed in the near future.

11.3.i Closed-choice response mode

The closed-choice picture-pointing response mode ensures that participants are not disadvantaged by difficulties with written or spoken language, and enables the test to be used in investigating the relationship between speechreading and reading. However, it also means that retrospective top-down information is available from the pictures for each item. This results in elevated scores by facilitating lexical access and selection. A number of participants commented that they were not able to decode the speechread item *before* they saw the pictures, particularly during the single words subtest. Post-speech context and guessing do have roles in everyday speechreading, but the test procedure presents the speechreader with different strategic cognitive choices than usually occur in daily life. In addition, guessing from a limited number of choices results in a higher proportion of correct responses than it would in an open

response test situation (or in everyday speechreading), and errors are less informative. The advantages of the picture-pointing response mode outweigh these limitations. However, open response subtests that do not place testees with poor expressive spoken or written English at a disadvantage would make a useful future addition to the test battery. For example, a subtest consisting of simple questions that could be answered in the participant's chosen communication mode might be expected to show more of an age effect due to caution (Honnell et al. 1991; Walden et al. 1993; see section 6.3.ii), because a response would not be forced each time. A greater relationship with risk-taking and impulsiveness may also be expected. In addition, correlations between open-response subtests and the existing subtests would add to the information about the concurrent validity of the TAS.

11.3.ii Additional subtests

It was particularly important that the speechreading assessments included here be kept short so that they did not dominate the testing battery, and a range of d/Deaf participants would participate (rather than just those who were more 'oral', or 'approved' of speechreading). It is hoped now, however, that this work can be built upon, and the test battery expanded to target further areas of interest. For example:

Context: The TAS currently includes no specific measure of top-down processing (although clues are available from the pictures retrospectively). A sentence- and/or story-level test, with context (e.g. a title or situation) provided for half of the items, but not for the other half would enable a measure of context use, or the benefit gained from context, to be determined for each participant. It is hypothesised that the provision of context will result in elevated speechreading performance (see e.g. Garstecki & O'Neill 1980; Pelson & Prather 1974; Sanders 1982; Stoker & French-St George 1984), but that the degree of benefit will vary between speechreaders. A greater benefit would suggest greater use of context, and this may be related to better speechreading performance on the TAS core tests.

Gesture and expression: A number of participants commented on the talkers' lack of facial expressions in the TAS. Facial expressions and gestures are further sources of top-down information in everyday speechreading, and the addition of message-related extra-facial gestures have previously been found to aid speechreading (this is supported by Rönnberg et al. 1998). A subtest in which message-related expressions

and gestures are available for some items (similar in design to that proposed for situational context) might therefore be a useful addition.

11.3.iii The Talkers

Feedback from the participants suggests that the two talkers used in the TAS are acceptable. The addition of extra talkers for future work would enable further questions to be addressed regarding, for example, normalization (see section 3.6; are testees who are better at normalizing across talkers better speechreaders?), and the possible difference between the deaf and hearing groups as a function of talker (see section 6.10.iii; is the speechreading performance of deaf participants more affected by talker than hearing participants?). The inclusion of talkers with different spoken accents would also widen the group of testees for whom the TAS is useful, and enable the effects of accent on speechreading to be investigated.

11.3.iv Further item selection

The results of the item analyses in Chapter 5 show that six of the fifteen story level subtests were performed at chance level. These items were therefore not discriminating usefully between testees. As part of the next stage in the test's development, these items will be replaced by slightly easier ones (with the exception of the second question of story C, in which the most commonly chosen distracter, 'tree', will be replaced; see 5.9.iii).

The difficulty level of the single word subtest will also be re-evaluated: closer distracters are planned to increase the difficulty of the subtest, and so that errors might be more informative. For each item, word-initially, -medially, and -finally similar distracters will be included as well as two unrelated distracters.

Further item selection is also required for the minimal pairs and focus tasks (see item analyses in section 7.7). The visual detection of focus proved possible, and performance on this task was highly predictive of general speechreading skill for the deaf participants (see Chapters 7 and 10). Further items could therefore usefully be added, and the visual cues available manipulated to investigate which are used in responding to the task, and whether these differ as a function of hearing status. It might be predicted, on the basis of the findings reported here, that deaf speechreaders tend to use vowel duration information, and hearing speechreaders, facial feature movements. Items with the video image manipulated so that the mouth movements

are overlaid on otherwise static facial images could be used to investigate this hypothesis.

11.4 Summary

In summary, the Test of Adult Speechreading (TAS) is a valid, reliable, discriminative and highly useable test, which is proving useful in investigating the speechreading abilities of d/Deaf and hearing British adults in a variety of contexts. Further test developments and additional subtests are planned to extend the test battery. Work has already begun to develop a similar test battery for children, and demand for this assessment is high.

Section B: Principal research findings

In this section, the remaining research questions posed in Chapter 1 will be addressed briefly (they have been focussed on in more detail in previous chapters). The principal findings of the thesis will then be drawn together and explored by considering two broad questions: Why are deaf adults better at speechreading than hearing adults? And, what makes a good adult speechreader?

11.5 Review of principal findings

11.5.i Did speechreading ability differ convincingly as a function of hearing status?

Deaf adults outperformed hearing adults on the Test of Adult Speechreading (TAS) (see section 6.13). The difference was robust: it remained significant even when only closely matched pairs of deaf and hearing participants were included in the analysis. This finding counters earlier generalizations suggesting that hearing people speechread better than deaf people (e.g. Mogford 1987). Rather, it confirms more recent studies showing that deaf people can outperform hearing people (Bernstein et al. 2000). It further extends this work since the deaf participants included here were not selected to be skilled speechreaders, as was the case in the study by Bernstein and colleagues (2000). There were no selection criteria based on language experience or preference, and every effort was made to ensure that testing procedures would not discourage any potential participants from volunteering. As a result, the deaf group was heterogeneous. The majority of the deaf participants were in fact culturally Deaf, preferred to use BSL, and did not consider speechreading to be important in the

majority of their everyday communication. Despite this, they outperformed their hearing peers on the TAS.

11.5.ii Were there subgroups of deaf and/or hearing adults with superior speechreading abilities?

The consideration of demographic variables in Chapter 6 showed that there were subgroups within both the deaf and hearing groups that showed superior performance on the TAS (see sections 6.14 and 6.11.ii). Within the deaf group, superior speechreading ability was shown by those who, through choice and/or experience, had greater familiarity with spoken language. That is, those who chose to wear hearing aids, grew up with spoken English being used in the home, and/or used some English (spoken or SSE) in their daily lives. Regression analyses showed that, of these, only hearing aid use and childhood home language had independent effects on speechreading performance. The subgroups of superior deaf speechreaders did not, however, account for the overall finding that deaf people were better speechreaders than hearing people: even the poorer-performing deaf subgroups out-performed the hearing group. In addition it should be noted that, despite the trends noted here, individuals can become extremely skilled speechreaders without using hearing aids or experiencing speech at home during childhood (e.g. DoH 16, see Chapter 10). The demographic variables did not have as great an impact on speechreading performance as (for example) lexical knowledge (see section 11.5.vii). These findings should not, therefore, be interpreted as implying that deaf children should experience spoken language rather than BSL to develop their speechreading skills. Many important factors need to be considered in decisions about the language approaches used with a deaf child (see Chapter 2, Sections B and C), and there is no evidence in this thesis that the use of BSL impacts negatively on speechreading ability: age at exposure to British Sign Language did not affect speechreading performance.

Within the hearing group, participants with deaf parents (the HoD group) performed significantly better than those with hearing parents (HoH) on the TAS. A group of late-signing hearing participants who were employed facilitating communication between deaf and hearing people did not show such speechreading superiority (see Study 6A). Thus, the superior speechreading skill of the HoD participants is unlikely to simply reflect their heightened awareness and knowledge of language and communication with deaf people. Rather, it is likely to be a result of their experience

of communicating with deaf people throughout their childhood and during the development of language. A decrease in speechreading skill with increasing age was also evident for the hearing group. This is likely to reflect presbyopic changes in the eye (see section 6.3.ii).

11.5.iii Were aspects of personality associated with speechreading ability for deaf and/or hearing adults?

There was a significant relationship between risk-taking & impulsiveness and speechreading performance for the deaf participants, but not for the hearing participants (see section 6.8.iii.d). Deaf participants who were more risk-taking and impulsive performed better on the TAS than those who were more controlled and cautious. This finding was expected since people who are more risk-taking and impulsive are more willing to guess. The visually perceived speech signal is, even for the best speechreaders, incomplete, poorly specified, rapid and transient. In everyday communicative speechreading, people who are more willing to guess are more likely to attempt to engage in communication where they will have to guess at the intended communicative message when they have understood only part of it. Their guesses can enable the communication to continue (where avoidance of guessing would have aborted it). More impulsive, risk-taking deaf individuals are more likely, therefore, to experience effective communication involving speechreading. It is important to note, however, that while the general trend within the deaf group was for better speechreaders to be more risk-taking and impulsive, relatively controlled, cautious individuals *can* be excellent speechreaders (cf. DoH 02, described in Chapter 10).

No relationship was expected, or found, between this personality factor and speechreading performance on the TAS for the hearing participants. Their willingness to guess will have had no impact on their experience of speechreading since they were not previously aware of speechreading. A relationship between willingness to guess and speechreading performance may, however, be expected even for hearing participants on open response speechreading assessments. On such assessments, participants who are unwilling to guess would be expected to attempt fewer items (in contrast to the TAS, on which a picture selection response is required for every item) (see e.g. Van Tasell & Hawkins 1981).

11.5.iv Did deaf and hearing groups show different patterns of speechreading performance or ability?

There were a number of differences evident in the patterns of speechreading performance demonstrated by the deaf and hearing participants (see Chapters 6 and 7). Overall, these indicate that, in comparison to the hearing group, the deaf participants:

- were more aware of their speechreading ability.
 - the correlation between self-rating and speechreading performance was significant for the deaf participants, but not for the hearing group.
- were more able to make use of facilitative aspects of the perceived speech.
 - for example, they were able to use the extra information available in spondees in comparison to monosyllables to perform better on the former in the single word subtest.
- were more able to segment the visually perceived speech stream.
 - a greater proportion of their errors on the sentence subtest items depicted aspects of the target sentence.
- showed evidence of having more, and/or more distinctive visemic categories (PECs, Auer & Bernstein 1997) than the hearing participants.
 - On the minimal pairs task, they were able to identify which of a pair of words was spoken with above chance-level accuracy when the words differed only in one phoneme from the same visemic category (e.g. fan / yan, card / cart).

The hearing participants, on the other hand, outperformed the deaf group on only one of the speechreading measures: the focus task. This is likely to reflect their audiovisual experience of focus (see discussion in section 7.12.vii).

11.5.v Can aspects of prosody be speechread?

The work reported in this thesis has demonstrated that one aspect of prosody, sentence focus, can be perceived through vision alone. Both deaf and hearing participants were able to respond to the focus task with above chance-level accuracy. Further, the regression analyses presented in Chapter 9 (section 9.4.ii, pg. 282-283), and the cluster analyses and multiple case studies in Chapter 10, suggest that the ability to identify focus may play an important role in the speechreading process for deaf adults. The theoretical implications of this are discussed in section 11.8.ii.

11.5.vi Was sensitivity to low-level visual form and/or motion related to speechreading ability in deaf and/or hearing adults?

Speechreading performance was found to be related to motion (but not form) coherence sensitivity for both deaf and hearing adults (see Chapter 8). That is, people who were more sensitive to visual motion (and therefore had lower thresholds for detecting coherent motion in random dot kinematograms) tended to be better speechreaders. However, the multiple case studies and *k*-means cluster analyses presented in Chapter 10 showed that, although the trend was for better speechreaders to have lower motion coherence thresholds, individuals can also be good speechreaders without being especially sensitive to motion – or poor speechreaders while demonstrating low motion detection thresholds.

11.5.vii Which language-related correlates of speechreading predicted individual differences in performance on the TAS?

Four language-related measures were included in this research in addition to speechreading: expressive English vocabulary, phonological awareness, reading, and forward digit span. Each of them correlated significantly with speechreading performance (and with each other; see Chapter 9). However, regression analyses (see section 9.4.ii) showed that vocabulary accounted for a greater proportion of the variance in speechreading performance on the TAS core subtests than phonological awareness or reading age (or than the demographic variables, hearing aid use, childhood home language and language preference). Of these language-related variables, only vocabulary made an *independent* contribution to predicting individual differences in speechreading performance on the TAS. The theoretical implications of this are discussed in section 11.8.iii, below, and in section 9.4.v).

Participant numbers were too small to include digit span in regression analyses, but the correlation analyses presented in Chapter 9 (see Table 9.5, pg. 277: the digit span–speechreading relationship survived controlling for vocabulary), and the *k*-means cluster analyses and multiple case studies presented in Chapter 10, suggested that working memory may also play an important and independent role in speechreading as measured by the TAS. Its pattern of correlations with the individual subtests suggests that it may be particularly crucial when processing demands are high, as they are in everyday speechreading.

11.5.viii Was there a relationship between speechreading and reading for deaf and/or hearing adults? If so, was it direct or mediated by other variables?

The results of Chapter 9 indicated that there was a significant correlation between speechreading performance on the TAS and reading age for the deaf participants. A significant relationship has also been found for hearing adults diagnosed with dyslexia (see Mohammed et al. 2006; and Appendix N). These variables were not related, however, for the (non-dyslexic) hearing participants, for whom reading was highly skilled and automated.

In both the deaf and dyslexic groups, reading and speechreading were inter-correlated with phonological awareness and vocabulary. In the deaf group, regression analyses suggested that the speechreading – reading relationship was mediated principally by vocabulary, and, to a lesser extent, phonological awareness (see pg. 286-288). In adults diagnosed with dyslexia, however, the speechreading-reading relationship was found not to survive when phonological awareness was partialled out, suggesting that the relationship in this group may be mediated to a greater extent by speech-based (phonological) representations. This suggests that speechreading and reading can be limited (or facilitated) by the same spoken language skills. In deaf adults, both are mediated by the group's limited lexical knowledge. In hearing adults with a history of dyslexia, on the other hand, these skills appear to be mediated by their more specific deficits in phonological processing (see Mohammed et al. 2006, and Appendix N).

11.5.ix Do the attributes and skills of individual expert speechreaders reflect the associations suggested by group comparisons and correlations?

The consideration of the attributes and skills of the best (and poorest) speechreaders in Chapter 10 both supported and extended the findings of the group comparisons and correlational and regression analyses from the earlier chapters. The participants who achieved the highest speechreading scores all showed good vocabulary, working memory capacity and reading skills, and also performed well on the focus task. They did not, however, form a homogenous group with respect to their other skills, preferences, attributes, or experiences. It seems there are many ways to become a skilled speechreader.

11.6 Summary of principal findings

In summary, the most important findings to emerge from this thesis were:

- Adults who are profoundly, congenitally deaf are able to speechread better than those who are hearing.
- A variety of factors, including hearing aid use, language experience and preferences, personality (willingness to guess), low-level visual skills, and spoken language-related knowledge and skills impact on speechreading ability as measured by the TAS.
 - Sentence focus can be identified visually at better than chance levels. Further, the regression, *k*-cluster, and multiple case study analyses suggest that sensitivity to this prosodic information is important in skilled speechreading.
 - Sensitivity to motion, but not to form, coherence is related to speechreading ability.
 - English vocabulary knowledge and verbal working memory appear to make independent contributions to speechreading ability.
- Whilst proficiency in English enhanced speechreading ability, there was no evidence that experience of, or use of British Sign Language had any impact on it.
- Reading and speechreading were related for deaf (and dyslexic - see Mohammed et al. 2006; and Appendix N) adults, but not for (non-dyslexic) hearing adults, for whom reading was skilled and highly automated.

The theoretical implications of these findings will now be considered in the context of two broad questions:

- a) Why are deaf adults better at speechreading than hearing adults?
- b) What makes a good adult speechreader?

11.7 Why are deaf adults better at speechreading than hearing adults?

Different speechreading tests deliver different findings dependent on a number of factors. For example, tests may load differentially on English vocabulary and syntactical competence, on working memory, or on additional factors such as literacy or speech intelligibility. The superiority of speechreading on the TAS by people who are deaf suggests that when these factors are reasonably well controlled, deaf people may make better use of visible cues to lexical identification than hearing people. Speechreading is, by definition, dependent on spoken language skills, but deaf people as a group (these participants included) are comparatively poor at all aspects of

English language. Why, then, do they outperform their hearing peers at speechreading?

Several findings from this and previous work offer clues: In Chapter 8, speechreading was found to be related to visual motion (but not form) coherence sensitivity. This, combined with neuropsychological dissociations (Campbell et al. 1997; Campbell & Perrett 1992), and demonstrations of visual speech processing with point light displays (Rosenblum et al. 1996) and images blurred by low-pass spatial frequency filtering (Munhall et al. 2004), suggests that the dynamic characteristics of seen speech, rather than the static, form-based characteristics (which do, nonetheless, play a role; see sections 3.4.i and 8.4), may be of primary importance in visual speech processing. The specific enhancements in processing peripheral motion shown by deaf people (Armstrong et al. 2002; Bavelier et al. 2000; 2001; Neville & Lawson 1987a; see section 8.3.i) may therefore afford them some speechreading advantage. For example, when the speechreader's foveal attention is not on the talker's mouth (speechreaders look frequently at the eyes of their communication partner; Lansing & McConkie 2003; Vatikiotis-Bateson et al. 1998), the articulatory movements of seen speech will be in peripheral vision, where sensitivity to motion is most acute. In addition, while the speechreader focuses their gaze on the talker's mouth (which is usual during, and immediately prior to speech, Lansing & McConkie 2003), other information giving clues about the message to be decoded (e.g. body language, the reactions of other perceivers) will be in their peripheral vision. Enhanced sensitivity to this information may facilitate speechreading.

Viewed within the framework of the primacy of time-varying articulatory information for speech perception (Liberman & Mattingly 1985; Remez et al. 1994; and see above), the sensory and perceptual information relevant for speech perception can be said to be 'modality-neutral' (Summerfield 1987): it can be carried by more than one sensory modality (Rosenblum & Saldana 1996). Because the acoustic and visual specifications of speech are produced by the same underlying articulatory gestures, they are systematically related to each other and to the underlying sensory-motor events that produce them (Vatikiotis-Bateson & Yehia 1996; Yehia et al. 1998; Yehia et al. 2002). Consequently, as long as information about the articulations of the vocal tract can be perceived, some degree of speech perception is possible. The skilled speechreading demonstrated by the best deaf speechreaders here (described in Chapter 10) and by others (e.g. Andersson & Lidestam 2005; Bernstein et al. 2000; Lyxell

1994) is testament to this. Indeed, even tactile information, perceived for example using the Tadoma method³⁶, can be used (Chomsky 1986; Keller 1903; Schultz et al. 1984) and integrated across sensory modalities (Fowler & Dekle 1991) in speech perception. However, although the information necessary for speech perception may be modality-neutral, the internal representation of speech must be based on an individual's experience with perceptual events and actions in the physical world. The phonological-lexical representations of deaf people are therefore likely to reflect their extensive experience with seen speech, and may, as a result, be better suited than those of hearing people for speechreading. In support of this suggestion is the finding that the deaf participants included here outperformed the hearing group on the minimal pairs subtest. They were able to identify the correct word from a minimal pair with above chance-level accuracy, even when the distinguishing phonemes belonged to the same visemic category. This finding is in line with that of Bernstein and colleagues (1997) that some deaf speechreaders are sensitive to visually perceived phonological distinctions that are generally considered 'sub-visemic'. It suggests that deaf people's extensive experience with visual speech in the near absence of auditory information may enable them to make use of visual cues that are not normally detected by hearing people: "The necessity for deaf individuals to attend to visual information can result in enhanced visual phonetic perception" (Mattys et al. 2002, pg. 672). The visual distinctions in the articulation of visemically similar words that cannot be distinguished by most hearing people (such as 'pat' and 'bat') can be seen clearly if viewed frame by frame (distinguishing features of 'pat' and 'bat', for example, include lip puff and tension) (Thomas 2006). Deaf adults may be sensitive to such cues in words. Since hearing people have access to very reliable and detailed speech information by ear, their experience in relying on seen speech is less consistent and less extensive than that of someone born deaf. The relatively poor speechreading skills of hearing people may therefore reflect relative (over-)reliance on the acoustic parameters of the speech stream.

In addition to, or perhaps because of, their superior visual phonetic perception, deaf participants show a superior ability to segment the visually perceived speech stream (demonstrated by their performance on the stories subtest, and particularly by the

³⁶ Tadoma (Alcorn 1932) is a method of communication used by deaf-blind individuals in which they learn to detect the phonetic properties of speech haptically, by placing their thumb and fingers on the talker's face and/or neck. It was developed by Sophie Alcorn, an American teacher at the Perkins School for the Blind, and named after the first two children to whom it was taught, Tad and Oma.

pattern of their errors on the sentence subtest, see section 6.10.ii), which makes decoding connected speech possible. Deaf people's experience with visual speech also makes them more accurate at rating their speechreading ability (see section 6.15). That is, they have an overt awareness of their speechreading skills which may enable them to 'work to their strengths' in understanding visually perceived speech.

11.8 What makes a good adult speechreader?

Multiple individual factors enter into an individual's speechreading abilities, and no single factor in isolation results in good speechreading skills. As discussed in section 11.5.i, the participants who were profoundly congenitally deaf reliably outperformed those who were hearing. However, deafness itself does not result in good speechreading: there were deaf speechreaders (the lowest-scoring participants in Chapter 10, for example) who performed no better than the hearing participants. In addition to hearing status, other factors have been identified here, through group comparisons, correlation and regression analyses, cluster analyses and multiple case studies, as being potentially necessary (although not sufficient) for skilled speechreading. These are lexical knowledge, the ability to visually identify sentence focus, and verbal working memory capacity. A range of further factors appears to facilitate skilled speechreading, although they are neither necessary nor sufficient for it. These include hearing aid use, the use of speech at home during childhood, sensitivity to visual motion, risk-taking & impulsiveness, and reading age. In other words, an individual does not *need* to use hearing aids, or to be especially sensitive to motion, or relatively risk-taking and impulsive, or to have comparatively skilled literacy abilities, to be a good speechreader – but it helps.

The implications of these findings are discussed further below.

11.8.i Demographic variables

The only demographic variable associated *consistently* with skilled speechreading was hearing status. Language experience and preference, and hearing aid use were associated with speechreading ability, but an individual can choose not to use hearing aids, and can have grown up with and continue to prefer to use manual communication, and still become a skilled speechreader (see e.g. participant DoH 16, Chapter 10). This is not surprising because there is no reason why BSL use should impair speechreading, other than the tendency for BSL users to have poorer English language knowledge and skills. Signers look at their communication partner's face,

not hands, when communicating (De Filippo & Lansing 2006; Muir & Richardson 2005; Siple et al. 1978; Sutton-Spence & Woll 1999), and lip patterns are used extensively in BSL. Nouns in particular have been found to be frequently accompanied by mouth patterns that were derived from spoken English: 87.5% of the nouns in Sutton-Spence and Day's (1997; 2001) corpus of naturally produced BSL signs were accompanied by a spoken component. The majority of the items in the word and story subtests of the TAS require comprehension of a noun, because they are the most easily represented by a picture.

Although hearing aid use and the experience of speech in the home during childhood are not *necessary* for the development of skilled speechreading, the regression analyses presented in Chapter 9 (pg. 280-281) suggest that the value for speechreading of these factors does not lie only in their tendency to be associated with better English language knowledge and skill. They made independent contributions in explaining the variance in speechreading skill over and above that explained by performance on the language-based tasks. Some of the benefit of experiencing speech at home from a young age may lie in the impact that this has on the overt awareness of speechreading as a skill. It was seen in Chapter 6 (section 6.15) that these deaf speechreaders were able to more accurately rate their speechreading skill than those who had experienced BSL or a mixture of language approaches. Increased awareness of speechreading may enable individuals to capitalise on their strengths and compensate for their weaknesses in speechreading.

The use of hearing aids by an individual suggests that they provide that individual with useful auditory and/or vibrotactile information. In day-to-day communication, the auditory / vibrotactile cues specify information about articulation that is not available visually, such as voicing. That is, from a motor theory / direct-realist point of view, they provide access to the movement and action of more internal articulators such as the velum. This information, combined with that available visually, enables the individual to develop a richer multimodal representation of speech, which in turn enables them to make greater use of speech (perception and production) in daily life. In addition, recent findings of higher levels of visual-only and audiovisual spoken word recognition in adult cochlear implant users compared with normally hearing adults (Rouger et al. 2007) suggest that experience of even a spectrally distorted but nevertheless available (temporally contingent) acoustic signal can lead to speech perception that makes use of both visual and acoustic channels beneficially. The

congenitally profoundly deaf hearing aid user may therefore have a relatively consistent, extensive experience of relying on seen speech, coupled with better-specified internal speech representations (in comparison to congenitally deaf non-hearing aid users). In addition, hearing aid use is a marker for language preference: hearing aid users are more likely to choose to use some English in their day-to-day communication (see Chapter 6, Table 6.10, pg. 185). Regular users of English are likely to have greater lexical, syntactic and pragmatic knowledge of spoken English, and to therefore be in a better position to decode and understand it through speechreading. The regression analyses presented in Chapter 9 (pg. 281-282) support this hypothesis: the variance in speechreading performance on the TAS core subtests that was explained by preferred communication mode was shared with that explained by English language knowledge and skill.

These findings highlight the importance of the development of English language knowledge in deaf education. It should be noted, however, that they do not have any implications for the use of BSL: the use of the two languages in education are not mutually exclusive. There is no evidence in this thesis of any specific impact of the use of BSL on speechreading ability: there was no significant relationship between age at exposure to BSL and speechreading performance, and no trade-off between BSL use and speechreading abilities. As discussed above, there were BSL users amongst the best speechreaders (e.g. participant DoH 16, see Chapter 10).

11.8.ii Identification of focus

The visual perception of prosody, and the role that this may play in speechreading, has received little attention in the literature. The results presented here, however, suggest that sensitivity to sentence level stress patterns may play a particularly important role in speechreading. The differences in meaning conveyed through focus in spoken English are conveyed differently in BSL. It is therefore not surprising that the ability to identify focus is related to English language knowledge (see Chapter 9, Table 9.11, pg. 289). However, conceptualising performance on the focus task as an indicator of knowledge about spoken language is not sufficient to explain its ability to predict individual differences in speechreading ability. Regression analyses showed that focus performance explained a significant proportion of the variance in speechreading performance on the TAS even after performance on the language variables had been accounted for (see Chapter 9, pg. 282-283). This suggests that

sensitivity to the visual cues indicating sentence focus may play a more direct role in the speechreading process. Prosodic information, such as focus, is carried in the systematic fine phonetic detail of the speech signal: the same attribute of the speech signal (acoustic and/or visual) can simultaneously contribute to many different abstractions (e.g. percepts of lexical form, prosody, talker identity and attitude) (Hawkins 2003). Which of these abstractions a perceiver is aware of may depend on factors such as the task in hand, and their experience. A speechreader's awareness of, and sensitivity to prosodic stress may be particularly important in segmenting the speech stream (see section 3.2.iii), and the results presented in Chapter 7 support this assertion (see Section 7.12.viii). Sensitivity to focus may also facilitate top-down processing. The ability to identify the focus in a sentence is the ability to identify where the emphasis in a sentence lies. The emphasised word is likely to be both the 'key' to the message, and comparatively easy to decode because its stressed status means it is less likely to be reduced by coarticulation. Individuals who are able to decode the focussed word, and to recognise it as such, may then be able to use this knowledge (top-down) in disambiguating the rest of the spoken message.

The goal of listeners, and speechreaders, is to understand a speaker's meaning – *all* of the meaning, not just that carried by the phonological segments and lexical items that could be transcribed. Information about the talker's attitudes and current state of mind, for example, is also crucial for successful conversation, and is carried by the same properties of the speech signal as the phonological-lexical information. From this standpoint, the evident importance of focus perception for speechreading is not surprising, and sensitivity to prosodic information might be expected to play an even greater role in successful 'real world' speechreading.

11.8.iii Lexical knowledge and verbal working memory

Spoken language knowledge is, self-evidently, fundamental to speechreading ability. The research presented in this thesis suggests that vocabulary knowledge and working memory span, particularly, are critical in speechreading. The evidence suggesting the importance of vocabulary was especially strong. It was found to make an independent contribution to explaining the variance in speechreading scores, was related to every measure of speechreading ability, distinguished well between good and poor speechreaders in a *k*-means analysis, and all of the highest-scoring speechreaders had good vocabulary scores. In addition, the regression analyses suggest that it is an

important factor underlying the relationship between reading and speechreading in people who are deaf.

As discussed in Chapter 9 (section 9.14.iv.a), it is not surprising that lexical knowledge has been found to hold such a central role in speechreading. Speechreading constitutes a primary means of acquiring spoken vocabulary for people who are congenitally deaf, and, reciprocally, their speechreading skills are limited by their vocabularies. Further, lexical processing is likely to be particularly important in visual speech perception, since bottom-up mapping is underdetermined (Samuel, 1996).

The correlation and cluster analyses, and multiple case studies also suggested the importance, and potentially independent contribution, of verbal working memory in speechreading. This is in agreement with previous studies that have identified working memory capacity as fundamental to the speechreading process (e.g. Lidestam et al. 1999; Rönnerberg et al. 1999; see section 9.1.ii). A strong relationship between these two measures was expected since speechreading makes heavy demands on on-line processing, and the efficient functioning of the phonological loop is considered crucial to the efficient processing of spoken language. However, a previous finding of an expert speechreader who did not possess the expected excellent verbal working memory capacity (the case of AA; Andersson & Lidestam 2005) suggests that it is not *necessary* in all cases for the development of skilled speechreading.

11.9 Limitations and future directions

11.9.i Sample size

Sample size was a limiting factor in this research. Although the participant numbers for the majority of the variables were adequate, the small numbers that completed the digit span task, and the motion coherence detection, and risk-taking & impulsiveness measures, precluded these variables from being included in regression analyses. It would have been advantageous to include digit span, particularly, since the results of the correlational and *k*-means cluster analyses suggest that it may play a particularly important role in speechreading. Additional participants would have enabled the relative predictive power of vocabulary, phonological awareness and digit span to have been assessed and contrasted, and the potential role of working memory in the reading-speechreading relationship to be further investigated.

11.9.ii Hearing people with deaf parents

Sample size was also an issue in considering the small group of hearing participants with deaf parents (HoD). The ten HoD individuals included in this thesis demonstrated superior speechreading in comparison to their contemporaries with hearing parents (HoH), and particular skills in the minimal pairs task. Further work with greater numbers of HoD participants is needed to establish whether the skilled speechreading demonstrated by these few is representative of HoD adults in general, and the reasons for this difference if it is.

11.9.iii Additional measures

English syntax: English syntactical knowledge and productive speech skills (articulation) were not measured in this study. The addition of these measures would have been useful in establishing the relative roles and predictive power of spoken language variables for speechreading. Both of these variables would be expected to inter-correlate with the other measures of spoken language knowledge, and therefore to be related to speechreading. A measure of syntactical knowledge would have been useful in establishing whether the strong relationship seen between speechreading and vocabulary reflects specifically the role of *lexical* knowledge in speechreading (and vice versa), or whether it reflects wider English language knowledge.

Speech production: Information on the deaf participants' productive speech skills would also have been particularly interesting. If time-varying articulatory information is assumed to be the object of speech perception (see sections 11.7 and 3.4.i), then it follows that all information available to the individual about a word's articulation, including kinaesthetic feedback from their own production of that word, will contribute to their internal articulatory representations. Accuracy of speech production would therefore be expected to be related to more efficient processing of visually perceived speech.

Proficiency in BSL: Investigating whether there is any relationship between BSL comprehension and/or production skills and speechreading performance on the TAS would be useful in supporting or countering the evidence presented here that BSL experience and use has no impact on speechreading ability (beyond the tendency for people who choose to use BSL alone to have poorer spoken language knowledge and skills). A BSL assessment that delivers scores for different linguistic levels (such as vocabulary and syntactical knowledge) would be particularly useful, since it would

enable potentially positive relationships between BSL and speechreading (such as vocabulary knowledge) to be explored.

11.9.iv People with dyslexia

The majority of the dyslexic participants included in the work reported by Mohammed and colleagues (2006) and in Appendix N were university students, and formed a high functioning, compensated, and therefore unrepresentative sample of the general dyslexic population. Further research with a more representative sample of dyslexic adult participants is needed to establish whether the findings apply to dyslexic adults generally. Similar, but stronger, correlations to those seen here would be predicted since the participants included here had relatively good language skills. The poorer language skills expected in a more representative dyslexic group would be expected to further limit their speechreading skills.

An additional area of interest, and of future research, concerns motion coherence sensitivity. The preliminary findings with deaf and non-dyslexic hearing adults (presented in Chapter 8 and 9) suggest that motion coherence sensitivity plays a role in speechreading for deaf and hearing adults, and in reading for deaf adults, whose reading skills are limited and not fully automatic. There have also been a number of studies showing that some adults with developmental dyslexia are less sensitive than control subjects at detecting coherent motion (e.g. Hansen et al. 2001; Talcott et al. 2000; Witton et al. 1998). It will be interesting to see whether motion coherence sensitivity is related to reading in dyslexic adults as it is in deaf adults. The former may have elevated motion coherence thresholds and would be expected to have depressed reading skills. The latter also show depressed reading skills, but demonstrate motion coherence thresholds that do not differ from those of hearing adults (and have been found to have specific magnocellular enhancements, e.g. Armstrong et al. 2002; Bavelier et al. 2000; 2001; Neville & Lawson 1987a; see section 8.3.i). A further, related, question is whether motion coherence sensitivity has a role in the relationship between speechreading and reading in dyslexic individuals.

11.9.v Longitudinal developmental research

Adult group comparisons and correlational studies such as those described here allow the 'end product' of a skill such as speechreading and its relationships to be investigated. They are thus extremely informative. However, such studies do not provide information about causality or developmental trajectories. The next stage in

this investigation of speechreading should therefore be a longitudinal study looking at speechreading development, and the development of the skills that have been identified as being associated with it, in children. As mentioned in Section A, work has already begun on developing a test battery similar to the TAS for children (Kyle, in prep; see www.dcal.ucl.ac/Research/themes/themes3.html).

11.10 Final Conclusion

This thesis has described the development and use of a reliable, valid and sensitive speechreading assessment that is suitable for use with d/Deaf and hearing British adults: the Test of Adult Speechreading (TAS). It is hoped that the TAS will be a useful tool for researchers and clinicians in the future as its development continues. The results of investigations using this new test provide compelling evidence that the speechreading skills of adults who are profoundly congenitally d/Deaf are better than those of hearing adults. A wide range of factors are associated with speechreading ability, including language and lifestyle choices and experiences, personality traits, low-level visual skills, and spoken language abilities. Of these, lexical knowledge and sensitivity to visually perceived prosody emerged as potentially necessary (although not sufficient) for skilled speechreading.

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APPENDIX A: Table of Examples of Extant Speechreading Assessments

The table below describes examples of extant assessments of speechreading. The list is not exhaustive, approaches taken (including tests not designed for this purpose), gives an overview of the history of speechreading assessments mentioned in the thesis. The assessments are arranged chronologically by the date that they were

AUTHOR(S); DATE; TEST NAME	COUNTRY OF ORIGIN	TEST MATERIAL	NUMBER OF TALKERS	MANNER OF PRESENTATION	MANNER OF RESPONSE & SCORING	TARGET POPULATION
Nitchie (1913)	USA	3 proverbs: 'Tis love that makes the world go round', 'Spare the rod and spoil the child' & 'Fine feathers make fine birds'.	One (male)	Filmed (moving-picture camera operated at a speed of 16 pictures per sec.)	--	Lipreading students
Kitson (1915)	USA	No formal test constructed – teachers' judgments of speechreading aptitude were used to rank subjects.	--	--	Subjects ranked	Adult lipreading students
Conklin (1917)	USA	8 consonants, 52 familiar words selected to present all the sounds of English, and 20 simple sentences, 10 from Nitchie's 1912 manual (see revised edition: Nitchie 1930), & 10 used regularly in the classroom by teachers for the deaf.	One	Live, each item repeated 3 times	Written; 1 point per consonant, 1 per word & up to 5 per sentence giving a possible total of 160 points	Deaf school pupils (adolescents)

AUTHOR(S); DATE; TEST NAME	COUNTRY OF ORIGIN	TEST MATERIAL	NUMBER OF TALKERS	MANNER OF PRESENTATION	MANNER OF RESPONSE & SCORING	TARGET POPULATION	NB
Day, Funsfeld & Pintner (1928)	USA	4 lists, each of 10 sentences	One	Live	Written	[unknown]	Described by Reid (1946) as the "first attempt at the objective measurement of lip-reading ability" (pg. 404). It was administered to 8300 pupils, but with "very limited success" according to Markides (1980, pg. 276)
Heider & Heider (1940)	USA	3 parallel series of: 30 nouns; 30 independent sentences; 2 stories.	One	Filmed	[unknown]	[unknown]	Described by Reid (1946) as "the most extensive report to date on the use of motion pictures" (pg. 404)
Mason (1942; 1943) A Cinematographic Technique for Testing Visual Speech Comprehension	USA	Test I: 5 simple nouns (e.g. baby) aimed at pre-school children; Test II: 10 slightly harder nouns (e.g. chair) Test III: An extension of 1 & 2 – adding 15 nouns, 5 included in the test but not introduced.	One (female)	Filmed (16mm motion-picture); black & white	Multiple choice: children were required to draw a large cross on the picture of the word spoken.	Deaf & HI children	2 forms (A & B) of each test. Ceiling effects: author suggests that it may be useful with young children (under 10 years). Mason planned to continue the test's development, but the work was not continued after her death in 1949 (Berger 1972b) Test materials reproduced in O'Neill & Oyer (1981, pg. 184-189)
Reid (1946)	USA	3 forms, each with 5 parts: 17 vowels & diphthongs, 11 consonants, 10 unrelated sentences, a series of related sentences telling a story (title of story & character names given), & a short story with 4 questions	Each form spoken by one different adult talker (2 female, 1 male)	Filmed (8mm, colour, lower ¾ of face & upper part of shoulders only)	Phonemes: multiple choice (underline word containing phoneme); Sentences: written; Story: answer questions	Deaf children	Author tested children in groups of 20-37. Problems recorded with asking children to give written responses: it doesn't allow children to demonstrate their full ability

AUTHOR(S); DATE; TEST NAME	COUNTRY OF ORIGIN	TEST MATERIAL	NUMBER OF TALKERS	MANNER OF PRESENTATION	MANNER OF RESPONSE & SCORING	TARGET POPULATION	NB
Utley (1946) "How well can you read lips?"	USA	2 forms of 31 sentences; 2 forms of 36 words; 6 stories (5 questions about each).	Words & sentences: one (a university co-ed) Stories: 4 (a small boy, a man & 2 women)	Silent film (1 hr 15) Words & sentences in black & white, stories in colour. Often presented live (or re- recorded, e.g. Calhoun et al. 1988) because of concerns that the talker was excessively difficult to speechread.	Written; Max score: 190	Deaf / HI children & adults	Standardised on 761 hearing impaired people aged between 8 and 21 years. This test served as a model for many later tests (Plant 1997). It was generally accepted as the most valid test of speechreading for many years, and used to estimate speechreading ability at the Hearing and Speech Centre at Gallaudet College in its 1 st 2 yrs (1958–1959). It was used for both clinical and research purposes as recently as the 1980s, but has now been supplanted by other measures. There were, however, criticisms re the test's validity and difficulty (see e.g. DiCarlo & Kataja 1951)
Morkovin (1947)	USA	10 everyday experiences followed by questions produced for speechreading training. One of these 'The Family Dinner' has been used as a speechreading test (see e.g. DiCarlo & Kataja 1951; Lowell 1975)	--	Filmed	Answer 20 questions related to the film's content.	--	This was not designed as a test: Morkovin (1947) simply advocated teaching speechreading using real life material rather than drilling and developed the films for that purpose. Films sometimes referred to as the 'Morkovin-Moore films'.

AUTHOR(S); DATE; TEST NAME	COUNTRY OF ORIGIN	TEST MATERIAL	NUMBER OF TALKERS	MANNER OF PRESENTATION	MANNER OF RESPONSE & SCORING	TAR POPUL
Pauls (1947)	USA	Continuous discourse: "carefully selected and edited commercial shorts, cuttings from feature pictures, and also certain Navy training films" (pg. 269)	Several - varies between film clips	Filmed (could be presented with or without sound)	[not specified]	Deafen and HI at U.S. Hospit
Cavender (1949)	USA	4 sets of 10 practice and 45 test sentences. Words selected to be within the reading vocabulary of the 1 st 3 grades.	one	Live, without voice	Multiple choice – underline the word (from a choice of 5) that occurred in the sentence	Hard-o hearing childre
Kelly (1953)	USA	3 sections: (1) 15 3-letter items (e.g. AIE, YBU, IGM, etc); (2) 10 'words out of context', 5 with 2 words to choose from, 5 with 3; (3) 10 sentences, 3-5 words long, 7 declarative, 3 interrogative.	one	Live or filmed	[unknown]	[unkno
Watson (1957) The New Manchester Picture Test	UK	8 lists of 10 CVC words, 5 in each designed to test vowel discrimination & 5 consonant discrimination	[unknown]	Live	Multiple choice picture pointing (black & white pictures)	Childre with (suspec hearing losses f yrs upw

AUTHOR(S); DATE; TEST NAME		COUNTRY OF ORIGIN	TEST MATERIAL	NUMBER OF TALKERS	MANNER OF PRESENTATION	MANNER OF RESPONSE & SCORING	TARGET POPULATION	NB
A Film Test of Lip- reading	Lowell & Taaffe (1957)	USA	2 equivalent lists of 30 sentences The two forms were constructed by ranking Keaster's 60 sentences & splitting them into 2 forms; (they had previously been in 6 lists of 10 sentences, each recorded with a different talker in b&w & colour).	One (male)	Film (16mm colour)	Written; 1 point for each correct word, possible total of 188 for each form.	Deaf / HI adults & children	This test is also called the 'Iowa-Keaster Test', and the 'Keaster Film Test of Lipreading'; it used Keaster's sentences, developed at the State University of Iowa. Spitzer et al. (1987) reported this test as widely used. Their results showed it to be easier than the CID sentences and the Gold Rush paragraph
	Donnelly & Marshall (1967)	USA	Development of Lowell & Taaffe's test, same 2 forms of 30 sentences, possible total now 30	One (male)	Film (with or without sound)	Multiple choice (derived from written responses)	Deaf / HI adults (university students)	
Moser, Oyer, O'Neill & Gardner (1960)		USA	1-syllable words taken from Voelker's (1942) list of the 1000 most frequently spoken words	Four	Film	[unknown]	[unknown]	
Harris, Haines, Kelsey & Clack (1961) Harris' Revised CID Everyday Sentences Lists		USA	Revision of the 10 CID everyday sentence lists (Silverman & Hirsh 1955) – key words retained, sentence length controlled more stringently. Each list has 10 sentences, and 50 key words.	Varies: usually one	Varies: usually recorded	Open response (spoken / written repetition); Key word scoring	Adults	Developed for <i>auditory</i> speech perception testing. These lists have been used widely for auditory, visual and auditory-visual testing, and translated into Finnish (Lonka 1995). This test has been found to be relatively difficult (see e.g. Spitzer et al. 1987).

AUTHOR(S); DATE; TEST NAME	COUNTRY OF ORIGIN	TEST MATERIAL	NUMBER OF TALKERS	MANNER OF PRESENTATION	MANNER OF RESPONSE & SCORING	TARGET POPULATION
Craig (1964)	USA	2 word tests, each of 33 groups of 4 words presented in the carrier phrase "show me ...". 2 sentence tests, each of 24 groups of similar sentences	One	Live (1 of each test presented with amplification, and one without)	Multiple choice (4 pictures with captions for each item)	HI children (aged 6 years)
Montgomery (1966) Donaldson Lip- reading Test	UK (Scotland)	40 sentences increasing in difficulty; 10 pages of 6-9 black & white line drawings, each page used 4 times	One	Live	Multiple choice (Picture pointing with photographs)	Children all school ages
Katt (1967, described by Smith & Kitchen 1972)	USA	2 lists of 16 unrelated sentences, mean no. words: 4, mean no. syllables: 4.53; 26 declarative, 5 interrogative, 1 exclamatory	One	8mm film / live	Written	Adults
Boothroyd (1968) AB Isophonemic word test		Lists of 10 CVC words built from the same 10 vowels and 20 consonants	One adult	Usually live	Repetition	Adults
Butt & Chreist	USA	Part A: informal checklist to be completed by an observer. Part B: identification of objects, numbers, colours, foods, animals, clothes, directions, adjectives & activities.	One	Live	Identification	Young children A: 2-24 B: 3yrs

AUTHOR(S); DATE; TEST NAME	COUNTRY OF ORIGIN	TEST MATERIAL	NUMBER OF TALKERS	MANNER OF PRESENTATION	MANNER OF RESPONSE & SCORING	TARGET POPULATION	NB
Myklebust & Neyhus (1970) Diagnostic Test of Speechreading	USA	Word, phrase and sentence stimuli. Lexical items recur in different sections of the test	[unknown]	One film in 2 parts	Closed-set picture identification	Deaf children (4-9yrs)	Holmes & Green (1976) reported scores well below the published norms for their deaf children. This test "does not appear to have been used extensively for investigative studies" (O'Neill & Oyer 1981, pg. 30)
Nielsen (1970)	Denmark	9 sentences (4-9 words) in an everyday scene: 2 adults drinking coffee. Simulated everyday situations used so that the analysis of situations through gestures was possible	Two adults	Colour film, without sound, length: approx. 4 minutes	Verbal repetition; Sentences scored as correct (1 point) or incorrect (0 point)	Hearing impaired adults	Test gives an estimate of ability. 0-1 point: weak (20%); 2-6 points: average (60%); 7-9 points: good speechreader (20%).
Ludvigsen (1974) (Pilot study: Ewertsen 1973) The HELEN Test	Denmark	8 lists of 25 relatively simple questions requiring a 1 word response in 5 broad categories (before/after, colours, opposites, arithmetic, miscellaneous)	One	Recorded; often presented in a noise background	Verbal – 1 or 2 word answer to questions	Adults	Has been translated & adapted for other languages (see e.g. Lonka 1995: Finnish; Plant et al. 1982: Australian English)
Skamris (1974)	Denmark	Numerals, place names, and short sentences about eating or meals	One	Live	Verbal repetition	Adults	Very short: administration time approx 3 minutes; Good correlation between test scores and ratings by therapists, family members and the participants themselves.

AUTHOR(S); DATE; TEST NAME		COUNTRY OF ORIGIN	TEST MATERIAL	NUMBER OF TALKERS	MANNER OF PRESENTATION	MANNER OF RESPONSE & SCORING	TARGET POPULATION	NB
Binnie, Montgomery & Jackson (1974; 1976)		USA	20 consonants in CV environment with /a/, each repeated 5 times in a random order (total 100 items)	One (female)	Film without sound	Written. Fixed choice of consonant.	Adults	Authors suggested use of test to ID people for consonant recognition. Training. Walden et al. (1977) used a 400- item version of this test to identify the number of visemic categories their participants could identify pre- and post- training.
Jones & Whitehead (1975) The NTID (National Technical Institute for the Deaf) Phoneme Identification Test		USA	15 CV syllables (consonant + /a/), each appearing 8 times giving a total of 120 items	One	Video, with sound	Circle consonant from closed choice on an opscan answer sheet	Hearing impaired adults	Designed as a test of <i>auditory</i> perception, and used for student placement in communication center courses at the NTID. Computer scoring yields total % score & % scores for consonants grouped by manner and place.
The National Acoustics Laboratory (NAL) Lip Reading Test	Plant & MacRae (1977)	Australia	5 lists (identical in all but their presentation order) of 20 CV syllables: the 20 English consonants /p, b, m, t, d, n, k, g, f, v, θ, ð, s, ʃ, dʒ, tʃ, w, r, j, l/ combined with /a/. Each syllable is preceded by the carrier phrase 'Please say ...'	One	Video (black and white)	Spoken repetition	Adults with acquired hearing impairments	Confusion matrices from 30 subjects (aged 18-50 yrs, with unknown hearing losses) produced 7 confusion clusters: (1) bilabials, (2) labiodentals, (3) interdental, (4) rounded labials, (5) alveolar continuants & velar stops, (6) post alveolars, (7) alveolar fricatives & stops.
	Plant, MacRae & Pearce (1980); Plant & MacRae (1981)	Australia	50 simple questions, mostly answerable with 1 word, in 5 categories (e.g. questions about you). Sentence length: 3 to 11 syllables (mean: 6.6 syllables). Topic given prior to each set of questions.	Varies: usually one	Video (black & white or colour)	Responses to questions.	Adults with acquired hearing impairments	Test materials reproduced in Plant & Macrae (1987, pg. 205). Spitzer et al. (1987) reported on the NAL/West Haven test: a modification in which American idioms were substituted for the specifically Australian items.

AUTHOR(S); DATE; TEST NAME	COUNTRY OF ORIGIN	TEST MATERIAL	NUMBER OF TALKERS	MANNER OF PRESENTATION	MANNER OF RESPONSE & SCORING	TARGET POPULATION	NB
Kalikow, Stevens & Elliott (1977) Speech Intelligibility in Noise (SPIN) Test	USA	10 lists of 50 sentences, varying from 5 to 8 words in length: 25 high predictability & 25 low predictability sentences mixed randomly in each list.	Varies	Usually presented with background noise (e.g. speech babble)	Verbal repetition of last word in sentence; Only the last word (noun) of each sentence is scored	Adults	Test reported to be excessively difficult (Gagné et al. 1987a; Martin et al. 1983; Plant et al. 1984), e.g. Plant et al.'s participants scored a mean of only 7.96% (range: 0-27%). This test is considered useful, however, for evaluating the benefit of hearing aids or for cochlear implant evaluation.
De Filippo & Scott (1978) Continuous Discourse Tracking (CDT)	Varies according to script used	A prepared text. The sender (talker) reads from the text segment-by- segment for a pre-determined time period (usually 5 or 10 mins). If the receiver repeats a segment correctly, the next is read. If not, the sender repeats / paraphrases / etc until all the words are correctly identified.	One	Live, although components of it has also been incorporated into computer-based systems, e.g. Computer-Aided Speechreading Training (CAST) (Pichora-Fuller & Cicchelli 1986), and the Computer Assisted Speech- Perception Evaluation and Training (CASPER) program (Boothroyd 1991)	Exact repetition (spoken); Score = number of words correctly identified per minute	HI adults and children	CDT has been incorporated into many training programs for cochlear implant recipients (see Gagné et al. 1991b), and has been used to evaluate the performance of subjects using cochlear implants (e.g. Levitt et al. 1986), tactile aids (e.g. Cowan et al. 1991; De Filippo 1984), Tadoma (e.g. Reed et al. 1992), and tactiling (e.g. Plant & Spens 1986). It has limitations, however, as a speechreading test: talker, receiver and text variables (e.g. talker speaking style & proficiency in providing repair strategies, receiver assertiveness, complexity of text used, etc) make it "inappropriate as a test procedure" (Tye- Murray & Tyler 1988, pg. 226)

AUTHOR(S); DATE; TEST NAME	COUNTRY OF ORIGIN	TEST MATERIAL	NUMBER OF TALKERS	MANNER OF PRESENTATION	MANNER OF RESPONSE & SCORING	TARGET POPULATION	NB
Bench, Kowal & Bamford (1979) BKB (Bamford- Kowal-Bench) Sentence Lists	UK (Australian version: BKB/A, Bench & Doyle 1979)	21 lists of 16 sentences varying from 4 to 7 words in length, each list has a designated 50 key words	Usually one	Varies	Open response (spoken / written); key word scoring	HI children, > 8 yrs, mild- severe HL	A widely used English test of open-set sentence recognition; developed for speech audiometry. The sentences were developed from language produced by 240 eight to fifteen year old children in schools for the deaf in the Berkshire area.
Markides (1980) The Manchester Speechreading (Lipreading) Test	UK	2 lists of 33 CVC words (99 phonemes); 2 lists of 25 sentences (5 each of 2 wd, 3 wd, 4 wd, 5 wd, 6 wd = 100 words). Words & sentences selected after testing larger pool with 120 hearing 6 year olds	One	Originally live, no voice	Written or verbal repetition (tester writes response down); Words scored per phoneme, sentences per word	British HI children & adults	Later papers (Markides 1989a; 1989b) refer to 4, rather than 2, lists. Words mainly drawn from 'Words your children use – an infant vocabulary source for Leicestershire Education Committee' compiled by Edwards and Gibbon (1959)
Tyler, Preece & Lowder (1983) Tyler, Preece & Tye- Murray (1986; 1987) The Iowa Cochlear Implant Tests	USA	Medial consonant recognition test: 6 lists of 70 consonants presented in an [aCa] context, where C = /b d g p t k f v s z m n/. Vowel recognition test: 6 lists of 45 vowels presented in an [hVh] context, where V = /i e a æ ɜ u o/ Sentence Test: 6 lists of 30 sentences, varying in length from 4 to 7 words, with 88 key words per list	1 (male)	Laser videodisc	Repetition (consonants: closed choice from 14, vowels: closed choice from 9, sentences: open choice)	Adults	Sentence vocabulary drawn from BKB sentences (see above). Use of laser disc technology enables randomised presentation of test materials.

AUTHOR(S); DATE; TEST NAME	COUNTRY OF ORIGIN	TEST MATERIAL	NUMBER OF TALKERS	MANNER OF PRESENTATION	MANNER OF RESPONSE & SCORING	TARGET POPULATION	NB
Bannister & Britten (1982) Eyes and Spoken Language (EASL)	USA	5 tasks: (I) fill in the blank (noun); (II) sentence completion (modifier / verb complement); (III) sentence recognition, 1 key word given; (IV) sentence recognition, no cues; (V) question response	One	Video, no sound	Written	Hearing impaired adults	Test developed to assess how well a person uses linguistic constraints in responding to visual only spoken language
Boothroyd, Hanin & Hnath (1985) CUNY (City University of New York) sentence lists	USA	48 lists (since increased to 72, Boothroyd 1991), each of 12 sentences ranging from 3 to 14 words in length, with a total of 102 words in each list. The 12 sentences in each list were related to the same 12 known topics, and comprised 4 statements, 4 commands & 4 questions	One	Video-disc	Repetition; scored on number of words correctly identified	Adults	Designed to be used to test speechreading alone and when supplemented by F ₀ information. Strong practice effect seen over 1 st 8 or 9 lists administered. The CUNY sentences have been used in a number of studies investigating auditory & tactile supplements to speechreading (e.g. Boothroyd et al. 1988; Boothroyd et al. 1992; Hanin et al. 1988) and are used widely in clinical settings.
Bernstein & Eberhardt (1986a; 1986b) Johns Hopkins Lipreading Corpus	USA	Corpus I-II: Disc I: CVC words Corpus III-IV: Disc 2: sentences, referred to as the 'B-E sentences' (see e.g. Bernstein et al. 2000; Demorest & Bernstein 1992)	Two (1 male, 1 female)	Laser videodisc (see Demorest & Bernstein 1992 for a description of the recording details)	Typed repetition	Adults	The sentence recordings include the lists of CID (Central Institute for the Deaf) Everyday Sentences (Davis & Silverman 1970). The female talker has been found to be more difficult than the male (Demorest & Bernstein 1992).

AUTHOR(S); DATE; TEST NAME	COUNTRY OF ORIGIN	TEST MATERIAL	NUMBER OF TALKERS	MANNER OF PRESENTATION	MANNER OF RESPONSE & SCORING	TARGET POPULATION	NB
Spitzer, Leder, Milner, Flevaris- Phillips & Giolas (1987) The Gold Rush Paragraph	USA	A paragraph followed by 6 yes/no questions	One (either male or female)	Video (viewed on either a b&w or colour monitor)	Written responses to questions.	Cochlear implant candidates	This test did not provide an adequate range of scores, and was considered unsuitable for testing connected discourse.
Gagné Seewald & Stouffer (1987b) Visual Consonant Recognition Test	Canada	18 English consonants in /aCa/ context, each presented 5 times in random order (making 90 items)	One (female Canadian experienced in monitored live-voice speech production)	Video (colour)	Identification	Hearing / HI Canadian adults	
Tye-Murray, Purdy, Woodworth & Tyler (1990)	USA	50 primary sentences	Six	Laser videodisc	Verbal repetition	HI adults	Tye-Murray et al. (1996) found mean 66% words correct (range: 19 – 96%)
Gagné, Tugby & Michaud (1991a) Speechreading Test on the Utilization of Contextual Cues (STUCC)	Canada	208 test items consisting of 104 sentences, each presented in a related & unrelated context. Each item consists of an introductory sentence (related / unrelated to test sentence), then the test sentence.	One (female)	Video, without sound, slowed rate of speech, introductory sentences were spoken (silent) & captioned	Written; Key word scoring	Adults with an acquired hearing loss	Test items selected from 198 modified SPIN sentences. The authors reported that further test development was needed & warranted.

AUTHOR(S); DATE; TEST NAME	COUNTRY OF ORIGIN	TEST MATERIAL	NUMBER OF TALKERS	MANNER OF PRESENTATION	MANNER OF RESPONSE & SCORING	TARGET POPULATION	NB
Gnosspeilius & Spens (1992) The KTH tracking procedure	USA	A prepared text. Procedure as for CDT (see above), but segment length is pre-determined and the only repair strategy permitted is repetition. The number of repeats is pre-determined; once that limit is reached the receiver is shown the word on an LED display or computer monitor.	One	Live	Exact spoken repetition; Tracking rate and other data recorded by computer	Adults	Data recorded: tracking rate (words per minute identified correctly); ceiling rate (tracking rate for words identified on 1 st presentation); proportion of blocked words; number of repetitions; and number of words displayed following non- identification
Tye-Murray, Witt & Castelloe (1996) The Sentence Gist Recognition Test	USA	50 sentences, length 5 to 8 words, in 6 topically related sets (e.g. a restaurant), cued by short film clips. When subjects get an item wrong they are given a choice of 5 repair strategies (repeat, key word, elaborate, simplify, rephrase). Two practice sets were presented before testing began.	Thirteen talkers (8 female, 5 male; aged from childhood to middle age)	Laser videodisc; AV with 6 talker babble;	Multiple choice – picture illustrating each item from choice of 6	HI adults (Cochlear Implant users)	Score generated: no. of presentations needed for a correct response (best poss. score: 1.0). Mean reported by authors: 1.3 (range: 2.1 – 1.0). The SGR accounted for more of the variance in subjective responses to speechreading questionnaires than sentence or consonant tests. The most popular repair strategy was repeat, then rephrase, elaborate, simplify, key word.

APPENDIX B: Pool of Words for Single Word Subtest

Monosyllables

♦ Arm	<i>Chair</i>	Frog	♦ Lips	Snail
<i>Bag</i>	✱ <i>Cheese</i>	<i>Glass</i>	♦ <i>Map</i>	Snake
<i>Ball</i>	♦ ✱ Chips	<i>Gloves</i>	<i>Match</i>	<i>Socks</i>
<i>Bath</i>	<i>Coat</i>	<i>Goal</i>	Mole	<i>Spoon</i>
Bear	<i>Comb</i>	♦ ✱ Goat	Moon	Stamps
<i>Bed</i>	Cot	♦ ✱ Goose	<i>Mouse</i>	Star
♦ ✱ Bee	Cow	♦ ✱ Grapes	<i>Nose</i>	<i>Sun</i>
Bell	<i>Cup</i>	<i>Hand</i>	Owl	Swan
Bike	<i>Dog</i>	Hat	♦ ✱ Pan	Swing
<i>Bird</i>	<i>Door</i>	Heart	<i>Pear</i>	Tent
✱ Boat	Duck	♦ ✱ Hen	Pen	<i>Thumb</i>
<i>Book</i>	Ear	Horse	✱ Phone	Tie
♦ <i>Bowl</i>	✱ <i>Egg</i>	<i>House</i>	Pig	✱ Toe
Bridge	<i>Farm</i>	<i>Jug</i>	⁽⁶⁾ <i>Pipe</i>	♦ ✱ Toy
<i>Brush</i>	✱ <i>Fence</i>	Key	♦ Plane	<i>Train</i>
✱ Bull	Fish	<i>Kite</i>	Rings	<i>Tree</i>
<i>Bus</i>	✱ Fire	Knife	<i>Sheep</i>	Watch
<i>Cake</i>	Flag	✱ Lamp	<i>Shoe</i>	Wave
<i>Car</i>	♦ ✱ Fly	<i>Leaf</i>	<i>Shop</i>	✱ Well
Cat	<i>Foot</i>	✱ Leg	Slide	<i>Wheel</i>

Bisyllables (spondees in bold)

✱ Apple	Football	Mousetrap	<i>Sea-horse</i>
♦ ✱ Ashtray	Handbag	⁽⁶⁾ Mushroom	Snowman
Baby	<i>Handstand</i>	✱ Onion	Spider
Balloons	Headlights	Orange	⁽⁶⁾ Squirrel
♦ Blackboard	Hedgehog	⁽⁶⁾ Padlock	Suitcase
♦ Bookcase	⁽⁶⁾ Horseshoe	♦ Paintbrush	⁽⁶⁾ Sunset
<i>Bookshelf</i>	Hot-dog	Palm-tree	Table
Carrot	<i>Iceberg</i>	Peacock	♦ ✱ Teddy
<i>Classroom</i>	<i>Ice-cream</i>	<i>Picnic</i>	♦ ⁽⁶⁾ Toadstool
⁽⁶⁾ Cowboy	✱ Keyboard	<i>Popcorn</i>	Toothbrush
Curtain	Lemon	Present	Whistle
♦ Donkey	✱ Letter	✱ Rabbit	⁽⁶⁾ Windmill
<i>Doormat</i>	Light-bulb	Rainbow	
<i>Doorknob</i>	♦ Matchbox	Sandwich	
Eyebrow	Monkey	⁽⁶⁾ Scarecrow	

[words in italics are from the BKB sentences (Bench et al., 1979), and/or the Manchester Speechreading Test (Markides, 1980)]

KEY

- Red** Discarded – not considered suitable by profoundly prelingually deaf judges
- ♦ Discarded – not easily named by participants in pilot test
- ✱ Discarded – not easily named by 15 normal hearing adults
- ⁽⁶⁾ Discarded – rated 'less familiar' by both profoundly deaf familiarity judges

APPENDIX C:

Pilot investigations undertaken during initial development of the video version of the Test of Adult Speechreading (TAS)

Following the example of previous test developers (e.g. Gagné et al. 1991b) many of these preliminary investigations were conducted with normal-hearing participants. Ideally, all investigations would have been conducted with participants who were representative of the target population (profoundly congenitally deaf British adults). However, since this population is limited, this was considered impractical at this stage.

Pilot 1

The stimuli pictures were arranged in a booklet as follows:

- Single words: The 143 single word pictures remaining following scrutiny by two profoundly prelingually deaf adults (plus 'handstand', which had been discarded, but was included to make an easily divided number) were divided into groups of twelve so that no two words in a group were visually alike when spoken (such as 'bed' and 'bird', or 'dog' and 'door'). Each group consisted of eight monosyllables and four two-syllable words; of these, four monosyllables and two spondee words were chosen as target words. The pictures of each group were arranged randomly in a 3 x 4 grid on an A5 page.
- Sentences: The 14 groups of sentence stimuli each consisted of three target pictures, and six distracter pictures. These were arranged randomly in a 3 x 3 grid on A5 paper.
- Stories: The target picture and eight distracter pictures for each of the eight stories were arranged randomly in a 3 x 3 grid, with the context picture to the left of the grid, on A5 paper.

The target words, the sets of sentences and the stories were spoken, in that order, at a natural rate, alternately by the two talkers (one male and one female) who were going to speak in the final recording of the test, and recorded on a mounted camcorder in a well-lit room against a plain background. This recording was played without sound to a profoundly prelingually deaf woman (S₁) and two normal-hearing adults (one female: S₂, and one male: S₃).

Instructions were given as follows:

Single Words: The participants were asked to first name each picture on the response pages, to ensure that the vocabulary was available to them, and then to respond to the video by pointing to the picture that matched the word they saw spoken.

Sentences: The participants were asked to look at the pictures and then to respond to the video by pointing to the one picture that best matched the sentence they saw spoken. One set of pictures was discarded following the testing of S₁ because the pictures were described as “too busy” and therefore not clear.

Stories: The participants were asked to look at the context picture and then the grid of pictures, and then to respond to the video by pointing to the one picture that best matched the story they saw spoken.

Results:

Table C.1: Results of Pilot 1 (scores and mean scores for each subtest and the whole test).

	Words	Sentences	Stories	Whole Test
S ₁	65 / 72 (90%)	37 / 42 (88%)	7 / 8 (88%)	109 / 122 (89.3%)
S ₂	64 / 72 (89%)	35 / 39 (90%)	6 / 8 (75%)	105 / 119 (88.2%)
S ₃	48 / 72 (67%)	24 / 39 (62%)	2 / 8 (25%)	74 / 119 (62.2%)
Mean	81.9%	80%	62.5%	79%

These results demonstrated that, even among only three participants, the test produced a range of scores. Importantly, this pilot experiment also enabled the researcher to receive feedback from participants concerning the acceptability of the test format and the appropriateness of the pictures, and to investigate the length of response time required. The test format was found to be acceptable, although some practice items were needed, and the importance of the talkers' facial expressions became apparent (an inappropriate smile was very distracting). S₁ found the speech too fast during the story subtest, particularly that of the male talker. She also found the context picture of one of the stories distracting, and it was decided that this would be a demonstration item in the test so that the context picture could be explained. Twenty-two of the single word pictures were found to be inappropriate, since they were not easily named correctly (see Appendix B), and several of the sentence and story pictures were edited to eliminate confusions following comments from the participants. A response time

of approximately ten seconds was required, although this varied considerably between participants.

The picture stimuli (without the video) from this pilot were also shown individually to fifteen normal hearing English adults (9 male, 6 female; age range 19 to 28, mean age 23). They were asked to name the pictures from the single word subtest, then the target sentences and stories were spoken live, with voice, and they were asked to point to the picture that best matched the sentence or story spoken. This was to ensure that there were no ambiguities in the pictures, and that every item was possible when the stimuli were fully understood. Sixteen further single word pictures, one sentence set and one story were discarded following this investigation (see Appendix B), and several pictures were edited for clarity as a result of comments made.

Pilot 2

Words: 40 monosyllables and 20 two-syllable words were selected from the remaining 95 words (68 monosyllables and 27 two-syllable words, of which 16 were spondees), and divided into groups of twelve in a 3 x 4 grid as before. The selections were made such that no two words in a group were visually alike when spoken (that is, no pictures were included as deliberate distracters), and by an attempt to maintain a similar style across the pictures. Each group consisted of eight monosyllables and four two-syllable words; of these, four monosyllables and two spondees were chosen as target words. One group was designated as a practice set. The leftover words were kept as possible items for an alternative form of the test, which may be developed at a later date.

Sentences: Six sentence sets (five sets of three target sentences, and one set of three practice sentences) were selected from the remaining twelve in consultation with a colleague experienced in working with deaf testees. Again, the leftover items were kept for a possible alternative test form.

Stories: The remaining six stories (with one designated the practice item) were used in the second pilot investigation.

The target words, sentence sets and stories were spoken alternately by the two talkers (one male and one female), and recorded on a mounted camcorder, in a well-lit room against a plain background, as before. Ten seconds of blank screen was left for

responses between each word. This revised, shortened test was given to fourteen hearing English adults (8 male, 6 female; age range: 20 - 51, mean age: 34).

Results:

Table C.2: Results of Pilot 2 (scores and mean scores for each subtest and the whole test).

	Words	Sentences	Stories	Whole Test
N	24	15	5	44
Min.	15 (63%)	4 (27%)	2 (40%)	25 (57%)
Max.	23 (96%)	14 (93%)	5 (100%)	40 (91%)
Mean	19.0 (79%)	10.4 (69%)	3.1 (62%)	32.9 (75%)

These results were considered acceptable. The mean test score fell within the required range of 50% to 75% (see section 4.3.v). As expected, the subtests appeared to be in order of increasing difficulty. Two of the single words were changed, and minor adjustments were made to the picture groupings in the word subtest following an analysis of the errors. One minor change in wording was also made to the sentence subtest following comments made during the pilot investigation.

Pilot 3

The revised stimuli from the second pilot investigation were recorded professionally. In addition, each talker was recorded saying the days of the week, and instructions in BSL were recorded, signed by a native BSL user. This test was then presented to ten participants: five hearing (2 male, 3 female) and five profoundly prelingually deaf (2 male, 3 female).

The participants were instructed to watch the talkers saying the days of the week to familiarise them with their speaking patterns, and then to look at the picture booklet. For the single word subtest they were instructed to pause the video and name each picture on a page before watching and responding to the stimuli. There were two demonstration items and four practice items for this subtest, followed by the test items. For the sentence subtest the participants were told that they would have plenty of time to look at the pictures before they saw a sentence spoken. There were three practice items for this subtest. For the story subtest they were instructed to look at the context picture first for a clue about the story. There was one demonstration item and one practice item for this subtest. For all subtests, participants were encouraged to

respond to every item, even if they were only guessing. Each item's number was captioned to appear on screen immediately before the stimulus to alert the testee and tester.

The pictures were presented in a booklet as in the previous investigation, and the instructions were printed on card so that they could be spoken to hearing participants, or read by participants who chose to do so.

Results:

TABLE C.3: Results of Pilot 3 (mean scores of deaf and hearing participants).

	Words	Sentences	Stories	Whole Test
Hearing	19.2 (80%)	10.8 (72%)	4.0 (80%)	34 (77%)
Deaf	23.6 (98%)	12.2 (81%)	4.2 (84%)	40 (91%)

These results were higher than anticipated, especially the results of the deaf participants. This group had a maximum whole test score of 98%, and therefore a strong possibility of a ceiling effect. For this reason it was decided to eliminate the picture naming from the single word subtest. This part of the subtest had been included to ensure that the participants knew the vocabulary. However, no participant had any difficulty with the vocabulary, which had been selected to be accessible and familiar to the target population. Naming the items had increased the length of the test, and gave participants the opportunity to practice the lip patterns for the pictures, making the task easier, and possibly putting oral participants at an advantage. In the sentence and story subtests it was decided that the participants would no longer be allowed extended time to look at the pictures before seeing the stimuli, since this allowed participants the possibility of using strategies to simplify the task.

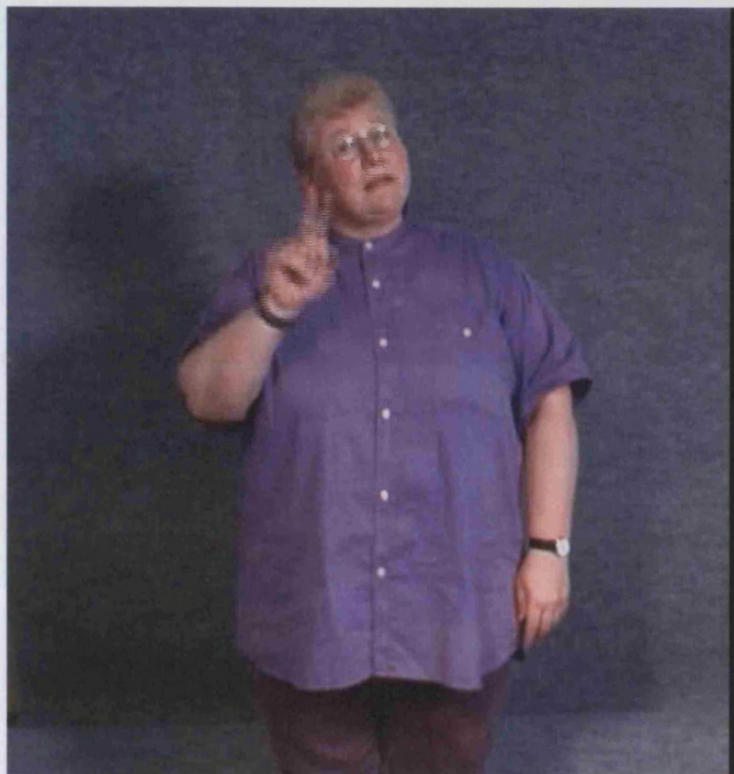
The signed instructions were also found to be very slow (the signer's autocue had been too slow during recording). Other than this, however, the test was considered suitable, and comments from the participants were positive. The test material was therefore not re-recorded: the video made had been found to be acceptable, and the modified instructions could be easily explained to the participants.

APPENDIX D:

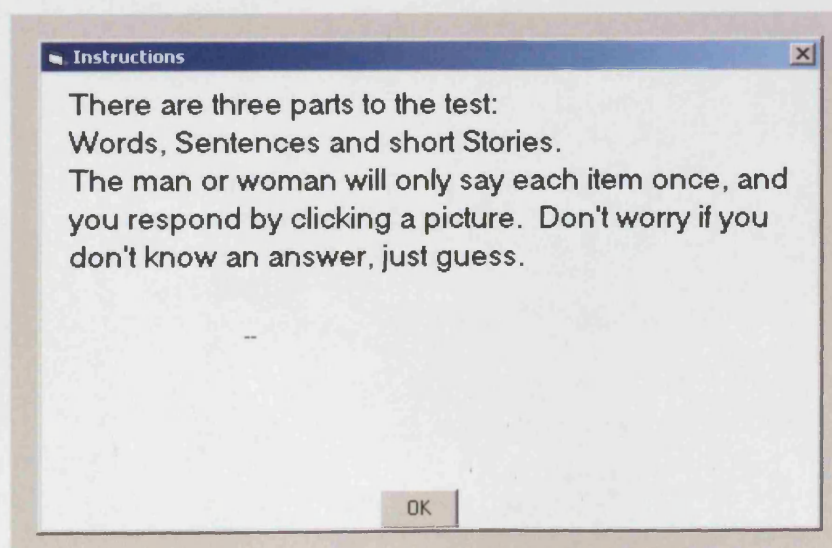
Test of Adult Speechreading (TAS)

Test items and Screen Shots

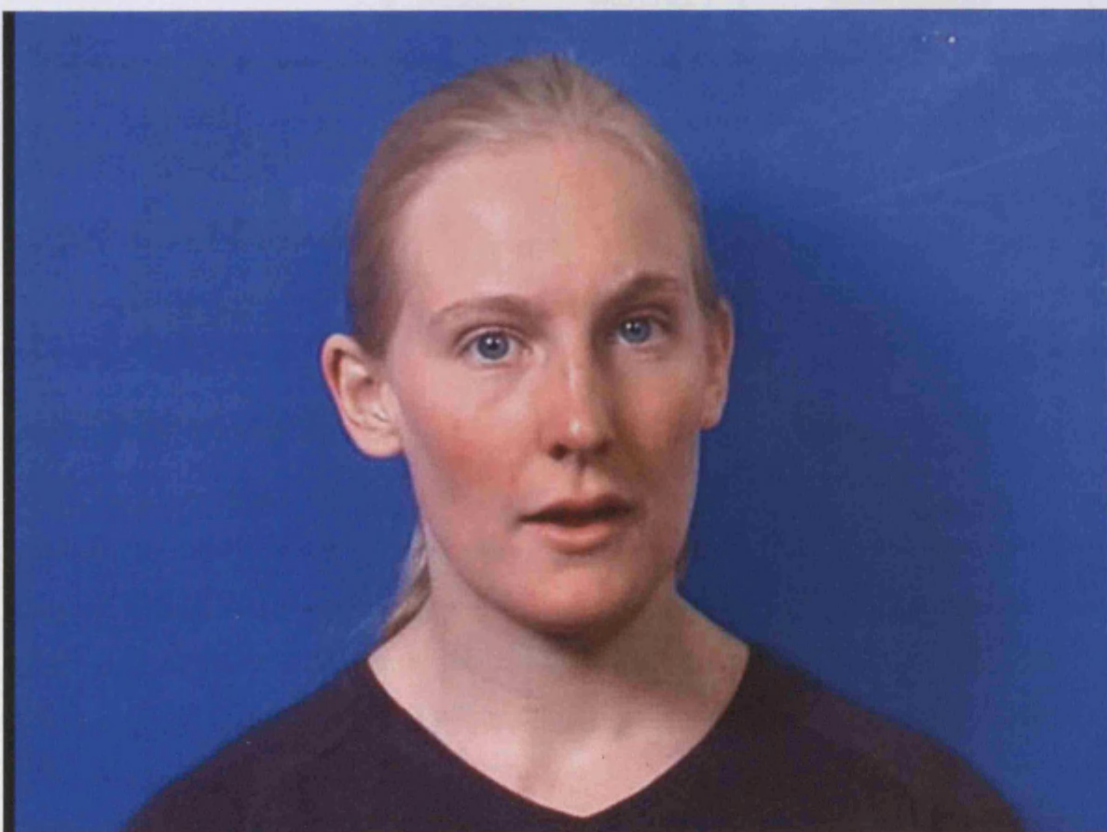
The test instructions, practice feedback, and the questions for the story items are available in British Sign Language:



Or in written English:



Two talkers present alternate test items in a head and shoulders view. At the beginning of the test they each say the days of the week for familiarisation.



CORE SUBTESTS

Single Words:








- | | | | |
|-----------|-------------|---------------|---------------|
| • Fish | 1. Dog | 6. Headlights | 11. Suitcase |
| • Watch | 2. Shoe | 7. Toothbrush | 12. Bed |
| • Tree | 3. Sandwich | 8. Rings | 13. Ice-cream |
| • Eyebrow | 4. Cup | 9. Key | 14. Cat |
| | 5. Door | 10. Pen | 15. Sun |

An example of single word response grid is shown below. This grid is used for the practice words, 'fish', 'watch', 'tree' and 'eyebrow'. Each of the test items is presented with a different response grid. It can be seen that the pictures are highlighted in red as the cursor moves over them.










For the practice items only, feedback is given: a tick or a cross, with the correct item highlighted. The correct word is provided in the chosen language: BSL or written English). The following screen shots illustrate this (with written feedback) for the single words subtest. The same feedback presentation is used for the other subtests. Notice also the 'ready' button at the bottom of the screen. This ensures that the testee is attending to the screen for the beginning of the next item, and that the mouse is not obscuring any part of the talker's face during the stimulus presentation that follows.

fish

 Correct!			
			

Ready

watch

 The answer was...			
			

Ready

Sentences:

- They're under the table.
 - She drinks on her own.
 - They're eating dinner.
1. The girl plays with a ball.
 2. Her mum pushes the swing.
 3. The teacher writes on the blackboard.
 4. The cow sleeps.
 5. The man walks the dog.
 6. He drops his ice-cream.
 7. The boy plays on the swing.
 8. They look at the computer.
 9. The sheep stands.
 10. They sit on the bench.
 11. The man sunbathes.
 12. The children run.
 13. The boy holds a book.
 14. He feeds the pig.
 15. The boy plays with the dog.

The screen shot below shows an example of a sentence response grid. This is the grid for the sentence *'The girl plays with a ball'*:



Connected Speech:

This subtest consists of 5 short stories, each with three questions presented in BSL or written English.

Practice: **Ben was going to the circus. On the way he stopped at a shop and bought a banana.**

- (a) Where was Ben going?
- (b) Where did he stop?
- (c) What did he buy?

A. **Last year I went on holiday with my dog. We stayed in a tent and went fishing every day.**

- 1. Who did I go with?
- 2. Where did we sleep?
- 3. What did we do?

B. **The little girl's favourite game is tennis. She also likes watching television, but she hates reading.**

- 4. What is her favourite game?
- 5. What else does she like?
- 6. What does she hate?

C. **My friend is in hospital. Last week he was skiing down a hill when he hit a rock and hurt his head.**

- 7. What was my friend doing?
- 8. What did he hit?
- 9. What did he hurt?

D. **The farmer drove into town on his tractor. He bought some carrots and took them home to feed his cow.**

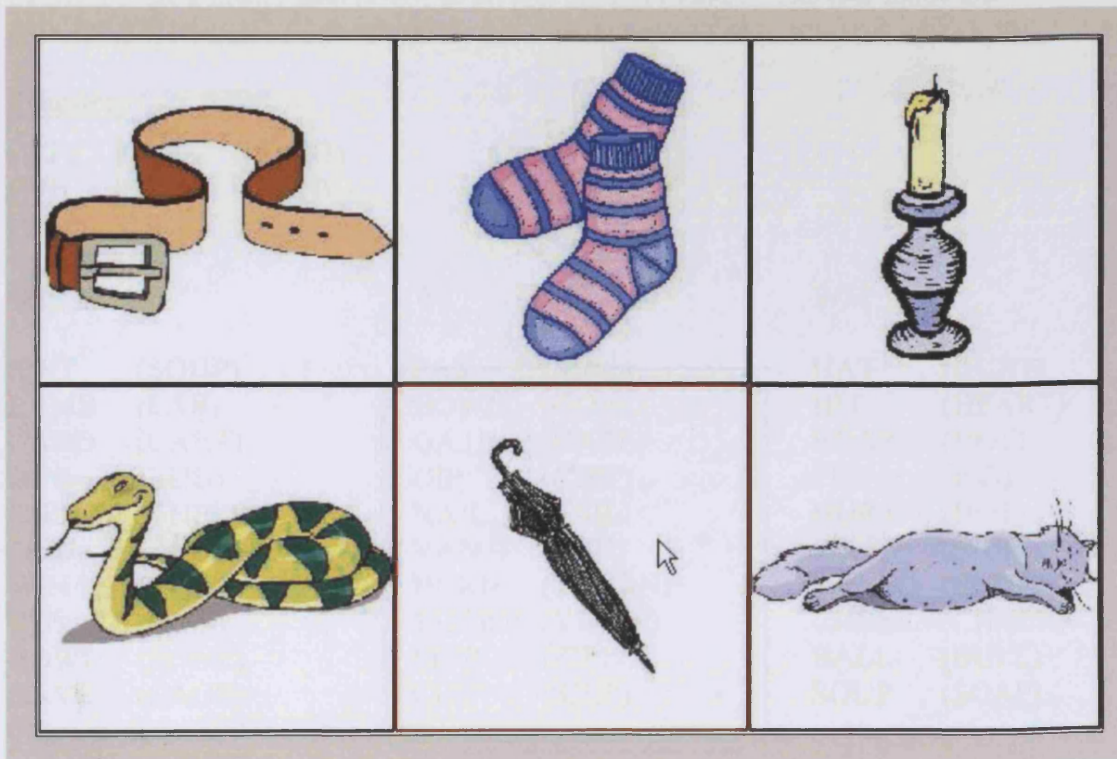
- 10. How did he get to town?
- 11. What did he buy?
- 12. Who were they for?

E. **Helen got up early, but forgot to put her glasses on. She went down stairs and saw a long shape in front of the fire. She called her husband to ask him what it was. He said it was only an umbrella.**

- 13. What did Helen forget?
- 14. Where did she see the shape?
- 15. What was it?

An example of a story response grid.

This is the grid for the final test item. The story was, *'Helen got up early, but forgot to put her glasses on. She went down stairs and saw a long shape in front of the fire. She called her husband to ask him what it was. He said it was only an umbrella.'* and the final question was *'What was it?'*



ADDITIONAL SUBTESTS

Minimal Pairs

30 CVC pairs 10 word final (consonant)
 10 word initial (consonant)
 10 word medial (vowel)

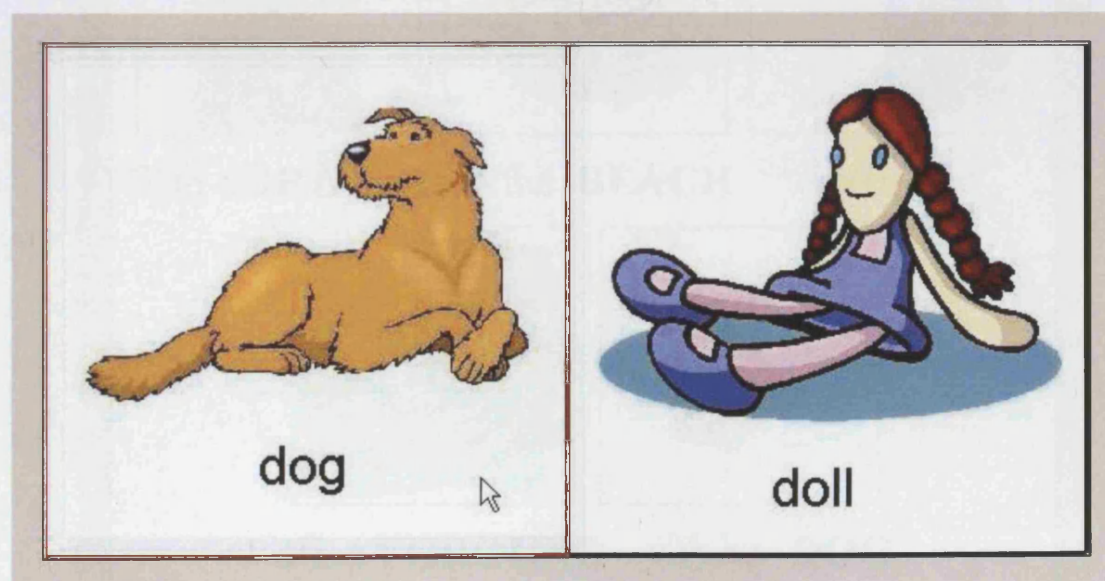
Each pair has a designated target word (on the left below). The test items are presented in a random order, half by the female talker and half by the male talker.

Practice:

[WF] KICK (KING)
 [WI] PHONE (BONE)
 [WM] SHEET (SHIRT)

WF		WI		WM	
SUIT	(SOUP)	PAT	(MAT)	HAT	(HURT)
LAMB	(LAB)	BOWL	(GOAL)	HIT	(HEART)
CARD	(CART)	GATE	(DATE)	HEART	(HOT)
BUG	(BUD)	DIP	(CHIP)	PEG	(PIG)
CHEEK	(CHEESE)	NAIL	(SAIL)	HURT	(HOT)
DOG	(DOLL)	VAN	(FAN)	SHEEP	(SHIP)
WIN	(WING)	HORN	(THORN)	SIT	(SUIT)
BUS	(BUN)	THORN	(YAWN)	CHEEK	(CHALK)
BOWL	(BONE)	SHIP	(ZIP)	BALL	(BULL)
CAVE	(CAGE)	CHIP	(SHIP)	SOUP	(SOAP)

A minimal pairs response grid (for the WF target 'dog'):








Focus

Task: Identify the word that is stressed or emphasised in the spoken sentence (which is seen written prior to speechreading). The target in each case is highlighted in red below. The practice sentence is seen twice: 'and' and then 'dog' are stressed.

*Practice sentence: The girl went to the beach **and** the playground with her **dog**.*

1. The dog and the **cat** chased a bird in the park.
2. The man had to take two buses and a train to his **house**.
3. The brown **monkey** jumped onto the man from the tree at the zoo.
4. The red bus overtook three cars and a **bike**.
5. My mum dressed our dog in sunglasses **and** a T-shirt.
6. The mouse stole **biscuits** and some cheese from the kitchen table.
7. Since Grandma got her glasses she's found **seven** coins under her bed.
8. My cat loves to eat fish and chicken on the **sofa** watching television.
9. My **rabbit** likes carrots but my rat and mouse prefer cheese.
10. The man brushed his teeth and shaved in the **bathroom** mirror.

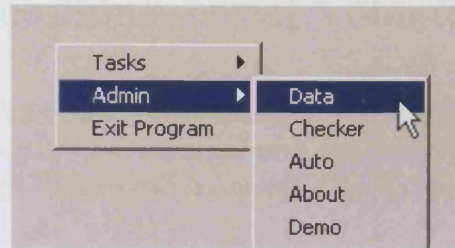
Each of these sentences was presented for familiarisation and response in a grid such as that shown below (this is the practice item grid). The sentences were seen written with five words (those underlined above) highlighted and pictured.

		
The GIRL went to the BEACH AND the		
		
PLAYGROUND with her DOG .		

Ready

Results

A testee's results are available from within the programme as soon as they have completed a task (see screen shots below). The data can also be opened in Excel.



The participant's responses

Whether they were correct (1) or incorrect (0)
(it can be seen that this participant scored 12/15 on the single word subtest)

C:\Program Files\TAS\Results\DFN48\DFN48 ENG TAS_words TEST.txt

Options

	1	2	3	4	5	6	7	8	
1 ball	0	22541	1 Chris_words	dog	cow	sun4	ball		
2 shoe	1	5064	2 Tara_words	house2	shoe	snowman2	slide3		
3 sandwich	1	7626	3 Chris_words	sandwich	peacock	tent2	ear2		
4 cup	1	18574	4 Tara_words	present	heart	hedgehog	cup		
5 horse	0	7142	5 Chris_words	horse	knife	brush	wave2		
6 headlights	1	12144	6 Tara_words	slide2	balloons	duck2	headlights		
7 toothbrush	1	1833	7 Chris_words	sun3	toothbrush	dog2	hedgehog		
8 snake	0	28161	8 Tara_words	swing2	table	snake	bird2		
9 key	1	3389	9 Chris_words	duck3	key	chair	whistle		
10 pen	1	3167	10 Tara_words	cup2	ball3	pen	snail		
11 suitcase	1	1343	11 Chris_words	cake	door2	orange	glass		
12 bed	1	4835	12 Tara_words	pig2	whistle2	bed	balloons2		
13 ice-cream	1	1581	13 Chris_words	hedgehog4	pen2	cup3	heart2		
14 cat	1	1969	14 Tara_words	bird	tent	cat	peacock2		
15 sun	1	8315	15 Chris_words	snail4	rhnn3	nresent2	cnw2		

Descriptive Statistics

	Groups	N	N correct	Total time	Mean time	Median time	Min	Max	SD	
1	0	15	12	69840	5820	4112	1343	18574	5181.91	

Response time (ms)

Descriptive statistics can be generated and viewed

The other information in the main panel gives the presentation order (column 4), videos and pictures used, the target picture and its position in the response grid (columns 5-14), and the talker (column 15)

APPENDIX E: Background Questionnaire (deaf participants)

Deafness, Language and the Brain project. Background Questions – Deaf Volunteers.

ID:

*Please answer the questions below and bring this with you to the research appointment.
If there are any questions that are not clear, please don't worry about it – we can go
through those when we meet. Thank you.*

Name: Mr / Mrs / Miss / other:	
Date:	
Date of Birth:	
Age:	
Gender: male / female	
Contact details: Address: Minicom: Fax: SMS (mobile): E-mail:	
Occupation:	
Which hand do you write with?	Right / Left
Which is your dominant hand for signing?	Right / Left
Do you wear glasses or contact lenses?	Yes / No
Do you know whether your level of deafness is classed as: mild / moderate / severe / profound? (please circle).	
Do you have a copy of past hearing test results? Yes/ no	
If yes, please could you bring it with you to the research appointment?	

How old were you when you became deaf?	
Do you know the cause of your deafness?	
How old were you when you were diagnosed?	
Do you wear hearing aids?	Yes / No
If yes - in which ear?	Both / Right / Left
- when do you wear them (how often, and in which situations)?	
If no - how old were you when you stopped wearing them?	
Do you have a cochlear implant?	Yes / No
Do you suffer from tinnitus?	Yes/ No
Details:	
Is your partner deaf?	Yes / No
Is anybody else in your family deaf?	Yes / No
If yes, who?	
Are most of your friends Deaf / Hearing / Mixture?	
What school(s) did you go to?	
Total communication / oral (please circle)?	
How many years did you spend in education (including college / university)?	
When did you leave school?	
What qualifications do you have?	
Have you done any courses since leaving school?	
Have you done any BSL or lipreading courses?	

Language history & use:

Preferred mode of communication: BSL / SSE / Speech / other: _____

How old were you when you were first exposed to BSL? _____

Did you start to learn BSL then? _____

Other language(s) or known: _____

(e.g. other Sign Languages, spoken languages, cued speech, Paget Gorman?)

Communication mode(s) used:...

when you were growing up: BSL / SSE / Speech / other: _____

with parents: BSL / SSE / Speech / other: _____

at school: BSL / SSE / Speech / other: _____

with deaf friends: BSL / SSE / Speech / other: _____

with hearing friends: BSL / SSE / Speech / other: _____

at work: BSL / SSE / Speech / other: _____

at home: BSL / SSE / Speech / other: _____

Where have you spent most of
your life?Please put down a number from the
map opposite to tell us where you
have lived most of your life:

Other: _____



***Thank you for answering these
questions. Please remember to bring it
with you to the interview session.***


We look forward to meeting you then!

APPENDIX F: Background Questionnaire (hearing participants)

Deafness, Language and the Brain project. Background Questions – Hearing Volunteers.

*Please answer the questions below and bring this with you to the research appointment.
If there are any questions that are not clear, please don't worry about it – we can go
through those when we meet. Thank you.*

Name: (Mr / Mrs / Miss / other:)	
Date:	
Date of Birth:	
Age:	
Gender: male / female	
Contact details: Address: Telephone: Mobile: E-mail: Fax:	
Occupation:	
Which hand do you write with?	Right / Left
Do you wear glasses or contact lenses? If yes, are you long / short sighted?	YES / NO
Do you know / spend time with deaf people? If yes: <ul style="list-style-type: none">• in what capacity? (e.g. family, friends, work colleagues, etc)• please see questions on last page	YES / NO

<p>How old were you when you left full-time education? (Please circle) 16 yrs or younger; 17 or 18 yrs; 19 yrs or over; still in full-time education</p> <p>What courses have you done since leaving school?</p> <p>What qualifications do you have / are you studying for?</p>	
<p>Is English your 1st spoken language? YES / NO</p> <p>If no: What is your first spoken language? How long have you been speaking English? Which other language(s) do you speak? _____</p>	
<p>Have you ever suspected that you might be dyslexic? YES / NO</p> <p>If yes, please see questions on last page.</p> <p>Have you been diagnosed with dyslexia? YES / NO</p> <p>If yes, do you have a copy of your clinical psychologist's report that you could bring to the research appointment? Otherwise, please see questions on last page.</p>	
<p>Do you suffer any long-term illnesses? YES / NO</p> <p>Details: _____</p> <p>Are you in good health? YES / NO</p> <p>Details: _____</p> <p>Do you suffer from tinnitus? YES / NO</p> <p>Details: _____</p>	
<p>Where have you spent most of your life?</p> <p>Please put down a number from the map opposite to tell us where you have lived most of your life: _____</p> <p>Other: _____ _____</p>	

If you have deaf friends / family....

Who is deaf in your family? _____

Can you use a signed language (eg BSL)? YES / NO

If yes:

• Which language(s)? (e.g. BSL / SSE / ASL / Auslan / cued speech / Paget Gorman) _____

• How old were you when you started to learn BSL (or other sign language)? _____

• Have you taken any BSL (or other sign language) courses? YES / NO

Details: _____

• What level of BSL (or other sign language) have you reached (e.g. native signer, stage 1, stage 2, etc)? _____

• Which is your dominant hand for signing? Right / Left

Have you done any lipreading / lipspeaking courses? YES / NO

Details: _____

If you are, or suspect you may be dyslexic:

• How old were you when you first thought you might be dyslexic? _____

• How old were you when you were diagnosed with dyslexia? _____ N/A

• Please describe briefly how dyslexia (or suspected dyslexia) affects you:

Thank you for answering these questions. Please remember to bring it with you to the interview session.

We look forward to meeting you then!

ID	Age	Gender	Audiometry & HL (dB)		Speechreading						Reading			NVIQ	Vocabulary	Phonological Awareness	Vision tasks		Digit span	Risk-taking & impulsivity
			Had copy	Tested	Rating	Pilot TAS	TAS core	Retest	Minpairs	Focus	GRT II	Kirklees	RA				Motion	Form		
DfSR01	40;2	M	98		✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓
DfLK02	39;3	F	106		✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
DfPB03	42;9	M	109		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
DfSJ06	29;7	F	>120		✓		✓		✓	✓		✓	✓	✓	✓	✓				
DfTC07	34;3	F		X	✓		✓		✓	✓		✓	✓	✓	✓	✓	✓	✓		
DfSG08	21;5	F	109		✓		✓		✓	✓	✓	✓	✓	✓	✓	✓				
DfDC09	43;5	M		104	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓
DfTW10	26;6	M		X	✓		✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
DfPG11	35;9	F		X	✓		✓		✓		✓		✓	✓	✓	✓				
DfNG13	29;3	F		103	✓		✓		✓	✓		✓	✓	✓	✓	✓				
DfMW14	21;8	F	100		✓		✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓
DfAR15	32;8	M		X	✓		✓		✓	✓	✓	✓	✓	✓	✓	✓				
DfJK16	32;4	M		>100	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
DfLF17	30;1	F	104		✓		✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓
DfPG18	44;4	F	>120		✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓				
DfTK19	25;11	F		>100	✓		✓		✓	✓		✓	✓	✓	✓	✓				
DfCG20	32;07	F		X	✓		✓		✓	✓	✓		✓	✓	✓	✓				
DfJW21	48;10	M	103		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
DfRW23	33;10	M		>100	✓		✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓
DfNK24	34;4	F		>100	✓		✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓
DfAH25	25;11	M	94		✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
DfIR26	37;1	F		X	✓		✓		✓	✓	✓	✓	✓	✓	✓	✓				
DfCR27	35;10	M		X	✓		✓		✓	✓	✓	✓	✓	✓	✓	✓				
DfCN29	60;1	F		X	✓		✓		✓	✓	✓		✓	✓	✓	✓				
DfRR30	34;10	F		99	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
DfMF31	22;1	M		>100	✓		✓		✓	✓		✓	✓	✓	✓	✓				
DfSS34	25;7	F		X	✓		✓		✓	✓		✓	✓	✓	✓	✓				
DfAT35	48;3	F		>100	✓		✓		✓	✓		✓	✓	✓	✓	✓				
DfNS36	30;10	F		>100	✓		✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓
DfCR37	36;7	F		X	✓		✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓
DfSD38	34;5	F	102		✓		✓		✓	✓	✓		✓	✓	✓	✓				
DfAL39	27;8	F		>100	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
DfHS40	26;6	M		>100	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
DfJG41	28;6	F	92		✓		✓		✓	✓	✓	✓	✓	✓	✓	✓				
DfPM42	53;05	F		>100	✓		✓		✓	✓	✓	✓	✓	✓	✓	✓				
DfMA43	32;0	M		92	✓		✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓
DfCR44	35;10	M		X	✓		✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		
DfLH46	39;6	F		X	✓		✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		
DfFG47	35;11	F		>100	✓		✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓
DfFN48	24;1	F		>100	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
DfDL49	56;11	M		X	✓		✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

Appendix G: Assessment battery tasks completed by the deaf participants (white: DoH; yellow: DoD)

ID	Age	Gender	Speechreading						Reading			NVIQ	Vocabulary	Phonological awareness	Vision tasks		Digit span	Risk-taking & impulsivity
			Rating	Pilot TAS	TAS core	Retest	Minpairs	Focus	GRT II	Kirklees	RA				Motion	Form		
HgMB04	32;0	F	✓		✓		✓	✓		✓	✓	✓	✓	✓				
HgSM05	21;6	F			✓		✓	✓		✓	✓	✓	✓	✓				
HgJD06	25;2	M	✓		✓		✓			✓	✓	✓	✓	✓				
HgHK07	20;11	F			✓		✓	✓		✓	✓	✓	✓	✓				
HgAB08	33;9	M			✓		✓	✓		✓	✓	✓	✓	✓				
HgKL09	19;9	F			✓		✓	✓		✓	✓	✓	✓	✓				
HgKM10	35;11	F			✓		✓	✓		✓	✓	✓	✓	✓				
HgMB01t	23;5	M	✓		✓		✓	✓		✓	✓	✓	✓	✓	✓	✓		✓
HgLH11	29;5	F			✓		✓	✓		✓	✓	✓	✓	✓				
HgCA12	26;5	F			✓		✓	✓		✓	✓	✓	✓	✓				
HgBC13	27;6	M			✓		✓	✓		✓	✓	✓	✓	✓				
HgGP14	24;6	F			✓		✓	✓		✓	✓	✓	✓	✓				
HgOP02t	28;8	M	✓		✓		✓	✓		✓	✓	✓	✓	✓				✓
HgJP15	28;7	F			✓		✓	✓		✓	✓	✓	✓	✓				
HgJW16	32;4	M			✓		✓	✓		✓	✓	✓	✓	✓				
HgPH17	47;10	M	✓		✓		✓	✓		✓	✓	✓	✓	✓				
HgKE03t	54;7	F	✓		✓		✓	✓		✓	✓	✓	✓	✓				
HgPR19	52;0	M	✓		✓		✓	✓		✓	✓	✓	✓	✓				
HgKW20	29;6	F	✓		✓		✓	✓		✓	✓	✓	✓	✓				
HgDB21	29;04	F	✓		✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓
HgMS22	56;05	F	✓		✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓
HgAA23	55;11	F	✓		✓		✓	✓		✓	✓	✓	✓	✓				
HgML09t	43;7	F	✓		✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		
HgCD10t	31;3	M			✓		✓	✓		✓	✓	✓	✓	✓				
HgSD11t	26;11	F	✓		✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		
HgJG12t	28;9	M			✓		✓	✓	✓	✓	✓	✓	✓	✓	✓			
HgSW13t	24;4	F	✓		✓		✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓
HgSM14t	37;7	F	✓		✓		✓	✓	✓	✓	✓	✓	✓	✓		✓		
HgIB26	38;2	M	✓		✓		✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓
HgRD15t	22;1	F	✓		✓		✓	✓		✓	✓	✓	✓	✓	✓	✓		
HgDF29	25;3	M	✓		✓		✓	✓	✓	✓	✓	✓	✓	✓				
HgSJ30	33;1	M	✓		✓		✓	✓	✓	✓	✓	✓	✓	✓				
HgAW31	50;5	F	✓		✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓
HgAP32	26;5	M	✓		✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓
HgMP33	57;3	F	✓		✓		✓	✓		✓	✓	✓	✓	✓				
HgSW18t	76;1	F			✓		✓	✓		✓	✓	✓	✓		✓	✓		
HgNA34	21;2	F	✓		✓					✓	✓	✓	✓	✓				
HgDG35	47;2	M	✓		✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓
HgMJ37	51;3	F	✓		✓		✓	✓		✓	✓	✓	✓	✓				
HgBB31t	16;0	M	✓		✓		✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓
HgLH34t	24;1	F			✓							✓			✓	✓	✓	✓

Appendix H: Assessment battery tasks completed by the hearing participants of hearing parents (HoH)

ID	Age	Gender	Speechreading						Reading			NVIQ	Vocabulary	Phonological awareness	Vision tasks		Digit span	Risk-taking & impulsivity
			Rating	Pilot TAS	TAS core	Retest	Minpairs	Focus	GRT II	Kirklees	RA				Motion	Form		
HgLS18	24;10	F	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
HgBP04t	46;4	F		✓	✓		✓	✓	✓	✓	✓	✓	✓	✓				
HgKG05t	24;0	F	✓		✓		✓	✓	✓	✓	✓	✓	✓	✓				
HgDT19t	22;9	F	✓		✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓
HgJM25t	25;3	F	✓		✓		✓	✓		✓	✓	✓	✓	✓	✓	✓		
HgEG32t	42;6	F	✓		✓		✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓
HgRS33t	24;1	M	✓		✓		✓	✓		✓	✓	✓		✓	✓	✓	✓	✓
HgRB35t	56;4	M	✓	✓	✓		✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓
HgJR37t	30;3	F	✓		✓		✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓
HgET40t	30;4	F	✓		✓		✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓

APPENDIX J:

Typical presentation order for the tasks in the assessment battery

- 1: Background questionnaire (often completed prior to the assessment session)
- 2: Risk / impulsiveness questionnaire
- 3: TAS core subtests
- 4: Audiometry (where appropriate)
- 5: Non-verbal IQ (block design from the WAIS)
- 6: First visual coherence task (motion or form)
- 7: Digit span
- 8: Phonological awareness tasks
- 9: Vocabulary production (adapted BNT)
- 10: Reading assessment (GRT II or Kirklees)
- 11: Second visual coherence task
- 12: (2nd Reading task if applicable)
- 13: TAS minimal pairs subtest
- 14: TAS focus subtest
- 15: Self-rating of speechreading ability

This order varied slightly between participants due to individual preferences and abilities: some flexibility enabled the administrator to maximise participants' motivation. However, this flexibility was constrained by the following limitations:

- The majority of the participants completed the questionnaires prior to the assessment session; otherwise, these were completed first.
- Speechreading: the TAS core subtests were always presented before the additional (minimal pairs and focus) subtests, and separated from them by other tasks. The minimal pairs subtest was always presented before the focus subtest, and these tasks were presented consecutively. Participants were not asked to rate their speechreading ability until after they had completed all of the speechreading tasks.
- The block design task was always administered early in the assessment battery because low non-verbal IQ was an exclusion criterion. Participants scoring below the 25th percentile on this task did not complete the remainder of the tasks.
- The computer-based tasks, and the two visual coherence tasks particularly (see Chapter 8), were interspersed with the reading, vocabulary and non-verbal IQ tasks to reduce eyestrain.

APPENDIX K: Vocabulary Test Record Form

[Adapted from the Boston Naming Test (Kaplan et al, 1983)]

ID: _____

Date: _____

No.	Picture	Response	Score
1	TREE		
2	PENCIL		
3	SCISSORS		
4	COMB		
5	SAW		
6	HELICOPTER		
7	MUSHROOM		
8	WHEELCHAIR		
9	CAMEL		
10	BENCH		
11	SNAIL		
12	VOLCANO		
13	CANOE		
14	GLOBE		
15	HARMONICA		
16	ACORN		
17	IGLOO		
18	DOMINOES		
19	HARP		
20	HAMMOCK		
21	STETHOSCOPE		
22	PYRAMID		
23	UNICORN		
24	ACCORDION		
25	COMPASS		
26	TRIPOD		
27	SCROLL		
28	SPHYNX		
29	PALETTE		
30	PROTRACTOR		

Comments:

Total Correct:

APPENDIX L: Investigation of Potentially Exclusionary Variables

Potentially exclusionary factors were investigated prior to the main analyses. During participant recruitment there was concern over

- participants with a late or unknown age at diagnosis (see section 2.6)
- participants with a non-genetic cause of deafness (see section 2.4)
- participants who opted out of audiometry (see section 6.6.ii)
- participants who suffer from tinnitus (see section 2.8)
- participants with a regional spoken accent different from that of the talkers (see section 4.4.iv)

These variables were recorded rather than being used as exclusion criteria to enable participant numbers to be as high as possible. However, their effect on speechreading performance was investigated prior to the analyses of the results so that participants could be excluded as necessary. In all analyses, the parametric assumptions of normality and homogeneity of variance have been met unless otherwise stated.

Age at diagnosis of deafness

Late diagnosis may cast doubt on the reported age of hearing loss. All participants reported being severely-profoundly deaf at birth, but this belief is unsubstantiated for those who were diagnosed late.

Twenty-eight (68%) of the deaf participants were able to report the age at which their deafness was diagnosed. As expected (see section 2.14), participants with deaf parents were diagnosed as deaf significantly earlier than those with hearing parents ($U=37.0$, $n=28$, 2-tailed $p<.01$). Table L.1 shows the breakdown of the deaf participant numbers, categorised by age at diagnosis. It can be seen that the majority of the participants were diagnosed before two years of age. Only two participants reported later diagnosis (aged two-and-a-half and four years respectively). Thirteen participants did not know the age at which they were diagnosed.

Table L.1: The numbers of deaf participants categorised by age at diagnosis of deafness

Age (months)	0-6	7-12	13-24	25-36	37-48	unknown
N	12	6	8	1	1	13

Late diagnosis was expected to be associated with poorer speechreading skills since it can exacerbate the effects of a deaf person's impoverished early language experience (see section 2.6). There was, however, no significant difference between the speechreading performance of the participants who were diagnosed within their first six months, those who were diagnosed later, and those who did not know the age at which they were diagnosed ($F_{(2,38)}=1.36, p=.270$; see Figure L.1).

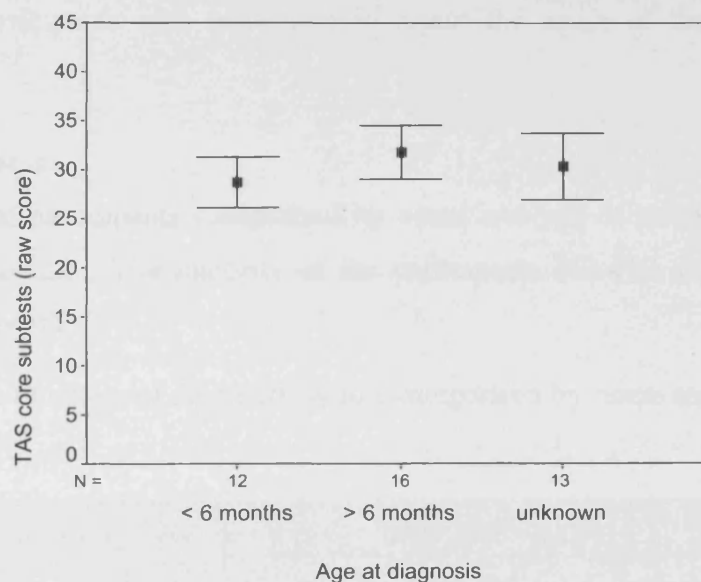


Figure L.1: The speechreading performance of the deaf participants categorised by their age at diagnosis (error bars show a 95% confidence interval)

It can be seen that the later-diagnosed participants (those diagnosed after six months) achieved a slightly (non-significantly) higher mean performance on the TAS core subtests than those who were diagnosed before six months. Since early diagnosis of congenital deafness enables adaptive communicative behaviour and amplification to be used, and has been found to be associated with better communication and language skills (e.g. Yoshinaga-Itano et al. 1998; Yoshinaga-Itano 1999; see section 2.6), this was unexpected and raised concerns that some participants may have had experience of functional hearing in early childhood. However, the findings in the literature of improved communication skills following early diagnosis are likely to reflect the

associated early intervention that the participants in those studies received (Yoshinaga-Itano et al. 1998). The work by Yoshinaga-Itano and colleagues was carried out in Colorado, where age of identification can be considered synonymous with age at initiation of intervention that focuses on improving the child's communication and language skills (Yoshinaga-Itano 2003). This is unlikely to have been the case for the participants included here: the ages at which they began to receive intervention, and the intervention itself, are likely to have been very variable (information about this was not available), and intervention is unlikely to have been immediately available following their diagnosis.

It is impossible to be certain that all of the unknown and/or late-diagnosed participants were congenitally deaf. However, further evidence is available for the majority of participants who were able to report the cause of their deafness (see section 2.4).

Cause of deafness

The numbers of participants categorised by cause and age of onset of deafness are shown in Table L.2. The majority of the participants (63.4%) reported that their deafness was genetic.

Table L.2: The numbers of deaf participants categorised by cause and age of onset of deafness

		Age at diagnosis			Total
		< 6 months	> 6 months	unknown	
Cause of deafness	Genetic	10	9	7	26
	Rubella	0	4	3	7
	Virus	0	1	1	2
	Undeveloped nerve	1	0	0	1
	unknown	1	2	2	5
Total		12	16	13	41

There was concern during participant recruitment that mild additional disabilities, not identified during screening, may be present in the non-genetically deaf participants, and that these may impact on their speechreading performance. If this were the case, the genetically deaf participants would be expected to outperform those whose deafness had other causes on the TAS. It can be seen from Figure L.2 that this was not

the case: the genetically deaf adults, as a group, performed slightly *less* well on the TAS than the other deaf participants, although this difference did not reach significance ($t(39)=-1.95$, 2-tailed $p=.058$).

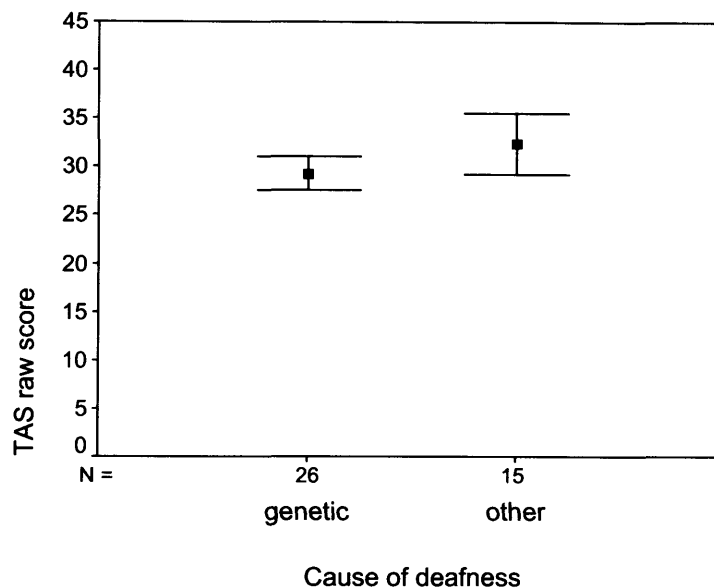


Figure L.2: The speechreading performance of participants whose cause of deafness was genetic, and those whose deafness had other causes (error bars show a 95% confidence interval)

The genetically deaf participants are likely to have been correct in their assertion that they were born deaf since the majority of cases of genetic deafness are congenital³⁷ (Morton 2002). Similarly, deafness due to maternal rubella is congenital, so although the 17% of participants who reported this as the cause of their deafness were diagnosed after 6 months, or did not know when they were diagnosed, they are highly likely to have been deaf from birth. There are, however, six participants for whom there is no specific evidence of congenital deafness: those whose cause of deafness was viral or unknown and whose age at diagnosis was post six months or unknown. There was no significant difference between the speechreading performance of these six participants and the rest of the deaf group ($t(39)=-1.64$, 2-tailed $p=.109$), however it can be seen from Figure L.3 that three of the six were amongst the best deaf speechreaders, scoring above 35 out of a maximum of 45 on the TAS.

³⁷ Approximately 77% of cases of nonsyndromic deafness are autosomal recessive, 22% autosomal dominant, 1% X-linked and <1% due to mitochondrial inheritance. Generally, people with autosomal recessive hearing impairments have congenital deafness, and those with autosomal dominant hearing impairments have postlingual and progressive deafness (Morton 2002; Morton 1991).

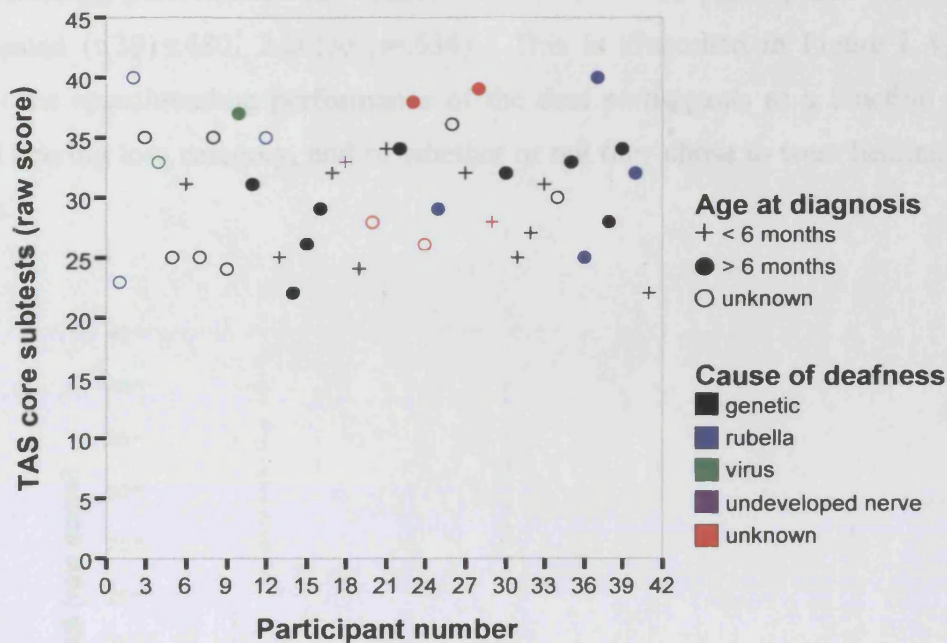


Figure L.3: The deaf participants' age at diagnosis, cause of deafness and speechreading performance

It was decided not to exclude participants on the basis of a lack of proof that they were congenitally deaf. Each of the participants reported that they had been born deaf, and the six whose age at diagnosis was post six months or unknown, and who became deaf through a virus or an unknown cause, do not differ from the rest of the group in terms of their speechreading performance. The deaf participants' results must, however, be interpreted with caution since the best speechreaders (those scoring over 35 on the TAS) were not diagnosed within their first six months (see Figure L.5, pg. 433).

Refusal of Audiometry

Thirteen of the deaf participants (6 DoD, 7 DoH) opted out of having their hearing tested, but self-reported profound hearing loss (see Appendix G, which details the tasks completed by each deaf participant). This raised concern that these thirteen may not have a hearing loss of over 90dB, since it had not been verified through testing. If these participants did have more hearing, a greater number of them may be expected to wear hearing aids, and they may be expected to perform better on the TAS. In fact, there was no significant difference in the proportion of the tested and untested

participants who used hearing aids ($\chi^2=1.333$, 2-tailed $p=.248$), and no difference in speechreading performance as a function of whether the participants' hearing level was tested ($t(39)=.480$, 2-tailed $p=.634$). This is illustrated in Figure L.4, which shows the speechreading performance of the deaf participants as a function of their tested hearing loss category, and of whether or not they chose to wear hearing aids as adults.

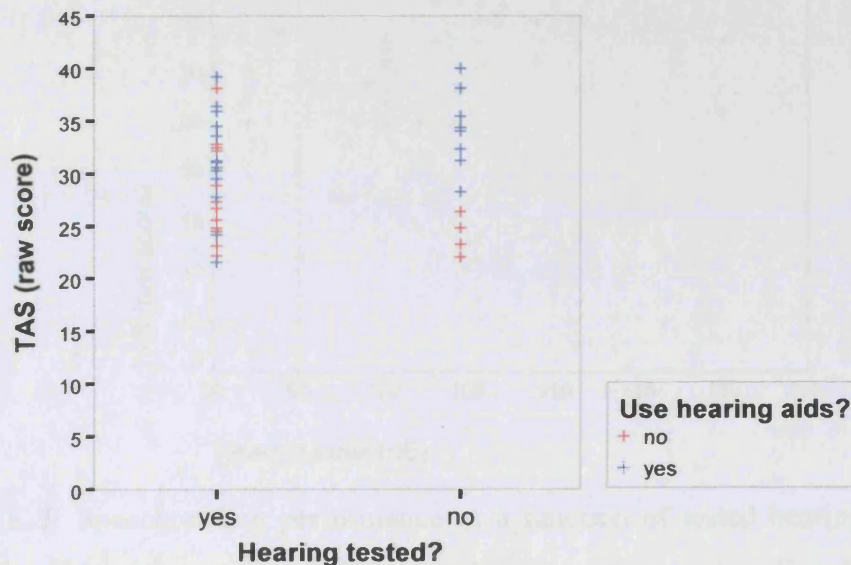


Figure L.4: The speechreading performance of the deaf participants as a function of hearing aid use and whether or not participants' hearing was tested

Amongst those whose hearing was tested, no participant was found to have a hearing level in a category below that that they reported. Three of the twenty-eight participants had a hearing loss below 95dB, categorised as severe (see section 2.2). The majority (25 participants) had hearing losses categorised as profound. Figure L.5 illustrates the speechreading performance of the participants as a function of their mean hearing loss in their better ear. Eleven of the participants tested had hearing losses of above 100dB, and two of above 120dB, that could not be precisely identified because they exceeded the maximum output of the audiometer used. These imprecise data are illustrated as red crosses in Figure L.5. They mean that it was not possible to statistically investigate the relationship, but it can be seen that speechreading performance did not decline as hearing loss increased, and there was no evidence of a systematic effect of hearing loss on speechreading.

Since there was no evidence that the participants who did not have their hearing tested were incorrect in reporting that they were profoundly deaf, they were not excluded from the studies. Within the very limited range of hearing losses included in this thesis there was no evidence of an effect of hearing level on speechreading performance, and this factor will not therefore be controlled for further.

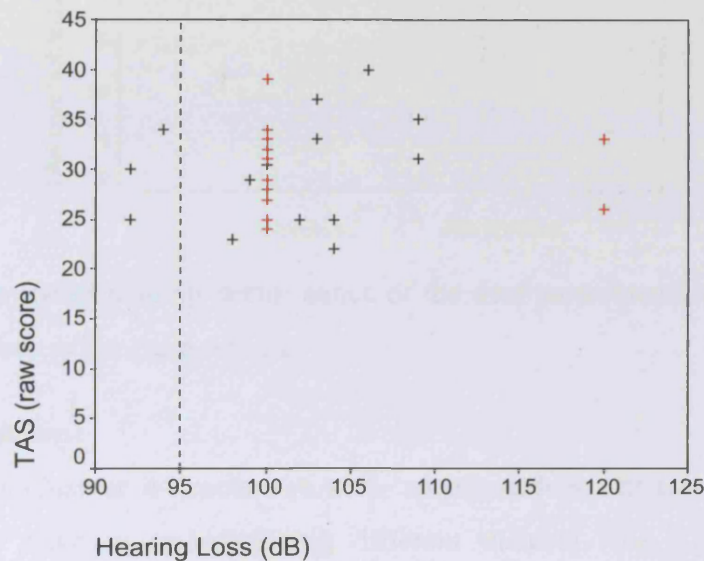


Figure L.5: Speechreading performance as a function of tested hearing loss. (The dotted line shows the categorical boundary between severe and profound hearing loss. Red crosses indicate that the participant's hearing loss was greater than the level recorded.)

Tinnitus

People who suffer from tinnitus may be expected to have lower speechreading scores because severe tinnitus may reduce the available attention resources (see section 2.8).

Nineteen of the deaf participants reported suffering from tinnitus, four of these only rarely. None of the participants reported severe or debilitating tinnitus. None of the hearing participants reported any tinnitus. There was no significant difference between the speechreading performance of the participants who suffered from tinnitus and those who did not (TAS core subtests: $t(39)=0.78$, 2-tailed $p=.439$), and as Figure L.6 shows, no participant with tinnitus scored unusually poorly on the TAS. No participant was therefore excluded on this basis.

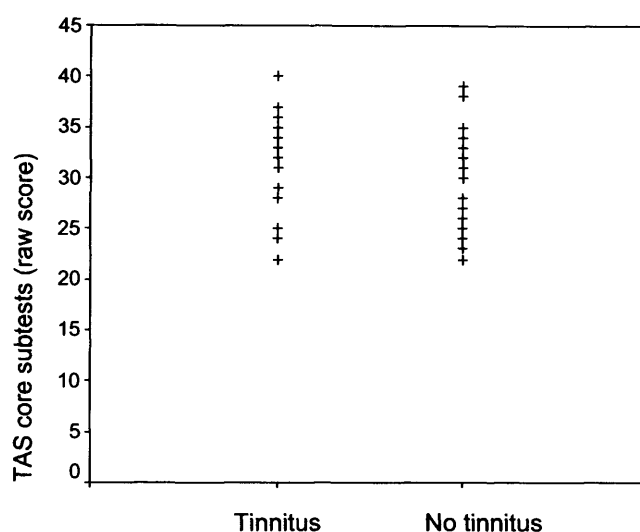


Figure L.6: The speechreading performance of the deaf participants as a function of whether or not they suffer from tinnitus

Local regional accent

As discussed in Chapter 4 (section 4.4.iv), speechreaders often comment on the difficulties they have in understanding different dialects (see e.g. Plant 1997). Participants who are accustomed to regional spoken accents that differ from the accent(s) of talkers in a speechreading test may be at a disadvantage because the greater the difference between the speech input and speech that is familiar to the speechreader, the greater the demand on the cognitive resources needed for 'normalization' (see section 3.6). The area in which the participants have spent the majority of their lives was therefore recorded, and there was concern that the talkers' accents may put those who come from a different area to the talkers at a disadvantage.

Table L.3 shows the numbers of deaf and hearing participants who reported spending the majority of their lives in each region. It can be seen that the majority of the participants shared the same regional spoken accent as the talkers (i.e. they had spent most of their lives in the South-East of England, where testing was carried out).

Table L.3: Frequencies of participants by the regions in which they reported spending the majority of their lives

Region	Deaf	Hearing
Scotland	2	1
N. England	1	1
Midlands	6	5
S.E. England	27	35
S.W. England	2	-
Wales	1	-
Ireland	-	1
Australia / NZ	2	4
USA / Canada	-	2
Other	-	2

Since participant numbers for the regions other than the South-East of England were very small, the deaf and hearing participants were grouped into those who had spent the majority of their lives in the same region as the talkers (deaf: $n=27$, hearing: $n=35$), and had therefore experienced a similar regional spoken accent every day, and those who had spent the majority of their lives in other areas (deaf: $n=14$, hearing: $n=16$). The speechreading performance of these subgroups for both the deaf and hearing groups is illustrated in Figure L.7.

There was no significant difference between the performance of the participants who shared the same regional spoken accent as the talkers and those who did not, for either group (deaf: $t(39)=-0.97$, 2-tailed $p=.339$; hearing: $t(49)=-1.05$, 2-tailed $p=.297$). The null hypothesis of no difference cannot therefore be rejected. The majority of the participants in this study have lived in more than one region, have travelled extensively around the country, and have experienced many different regional spoken accents throughout their lives. As a result, the talkers' accents are likely to have been familiar to them. The TAS may be expected to be more difficult for participants who are not familiar with a Southern English accent.

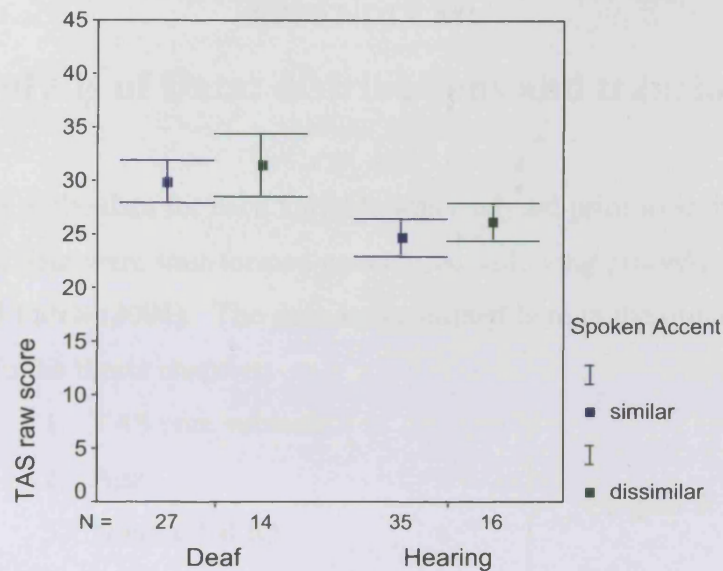


Figure L.7: Performance of deaf and hearing participants on the TAS as a function of the region in which they had spent the majority of their lives: similar or dissimilar to that of the talkers (error bars show a 95% confidence interval)

Summary

None of the participants were excluded on the basis of age at diagnosis, cause of deafness, refusal of audiometry, tinnitus, or regional spoken accent: these factors were found not to impact significantly on speechreading performance. There is no evidence to cast doubt on the deaf participants' reports that they were born deaf. However, since the best speechreaders' age at diagnosis was post six months or unknown, it is important to remember in interpreting their results the possibility that some may not have been profoundly deaf from birth.

APPENDIX M:

Initial Analysis of Data: distributions and transformations

The distribution of the data for each variable was analysed prior to an investigation of the results. The data were transformed as required following procedures proposed by Tabachnick and Fidell (2001). The data are examined here in the order in which they are considered in the thesis chapters:

1. TAS core subtests	}	Chapter 6
2. Age		
3. Non-verbal IQ		
4. Risk-taking & impulsiveness		
5. Minimal pairs subtest	}	Chapter 7
6. Focus subtest		
7. Digit span	}	Chapter 9
8. Vocabulary		
9. Phonological awareness		
10. Reading		

TAS core subtests

The TAS core subtest data were normally distributed for both the deaf and hearing groups: (deaf: Shapiro Wilk statistic = .964, $df=41$, $p=.211$; hearing: Shapiro Wilk statistic = .981, $df=41$, $p=.722$; combined: Shapiro Wilk statistic = .987, $df=82$, $p=.562$). These distributions are illustrated in Figure M.1. The raw scores were used in the analyses and did not require any pre-analysis treatment.

Considering the single word, sentence and story subtests individually, the hearing group's scores were normally distributed on all three (words: Shapiro Wilk statistic = .957, $df=41$, $p=.120$; sentences: Shapiro Wilk statistic = .957, $df=41$, $p=.119$; stories: Shapiro Wilk statistic = .959, $df=41$, $p=.147$).

For the deaf and combined groups, however, the data differed significantly from normal for the individual subtests (deaf group – words: Shapiro Wilk statistic = .863, $df=41$, $p<.001$; sentences: Shapiro Wilk statistic = .933, $df=41$, $p<.02$; stories: Shapiro Wilk statistic = .935, $df=41$, $p<.05$). Attempts at transforming the single words and

stories data did not produce normal distributions, and non-parametric statistics will therefore be used for analyses of these data for this group. Taking the square root of the inverted data ($\sqrt{(16 - \text{raw})}$) did, however, normalise the distribution of the sentence subtest data.

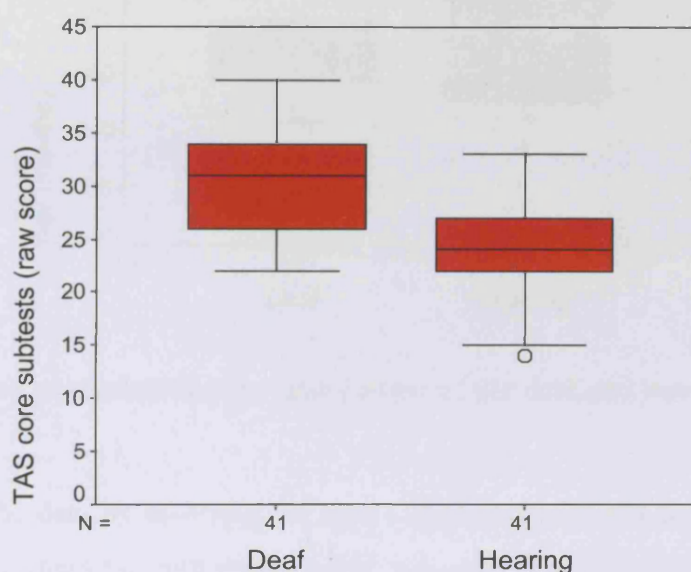


Figure M.1: Box plots showing the distribution of the deaf and hearing participants' scores on the TAS core subtests

Age at first exposure to BSL

The distribution of the deaf participants' ages at first exposure to BSL differed significantly from normal (Shapiro-Wilk statistic = .84, $df=41$, $p<.001$). Attempts to transform this data did not normalise the distribution. Non-parametric statistics were therefore used in analyses.

Age

The distribution of the participants' ages differed significantly from normal for both the deaf and hearing groups (deaf: Shapiro Wilk statistic = .934, $df=41$, $p<.05$; hearing: Shapiro Wilk statistic = .885, $df=41$, $p<.05$; combined: Shapiro Wilk statistic = .917, $df=82$, $p<.001$). The data were significantly positively skewed for both groups (deaf: $z_{\text{skewness}} = 2.54$; hearing: $z_{\text{skewness}} = 3.06$), and there were outliers for both. These distributions are illustrated in Figure M.2.

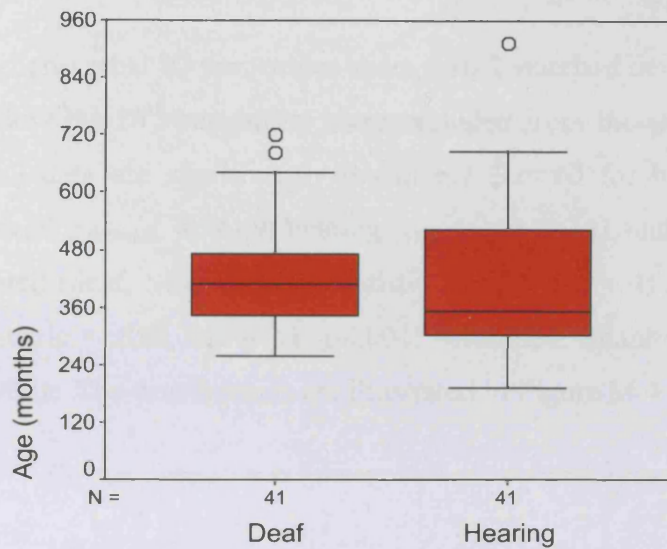


Figure M.2: Box plots showing the distribution of the deaf and hearing participants' ages

Transforming the data by inverting the ages ($1/\text{age}$) removed the outliers (see Figure M.3) and the skewness for both groups (deaf: $z_{\text{skewness}} = 0.87$; hearing: $z_{\text{skewness}} = 0.78$). The distribution of the transformed ages did not differ significantly from normal for either group, or for the groups combined (deaf: Shapiro Wilk statistic = .976, $df=41$, $p=.526$; hearing: Shapiro Wilk statistic = .971, $df=41$, $p=.364$; combined: Shapiro Wilk statistic = .979, $df=82$, $p=.210$).

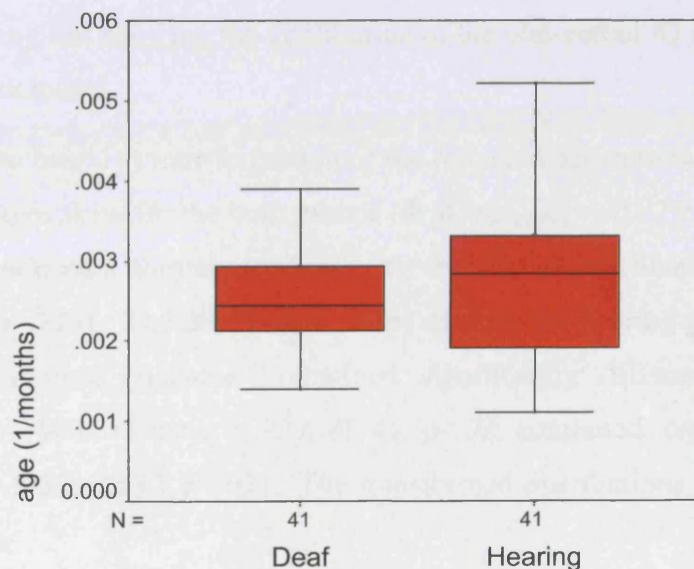


Figure M.3: Box plots showing the distribution of the transformed age data for the deaf and hearing participants

Non-Verbal IQ

Participants with non-verbal IQ percentiles more than 2 standard deviations below the mean (that is, below the 25th percentile) were excluded from the study. As a result, the non-verbal IQ data are significantly negatively skewed for both the deaf and hearing groups (deaf: $z_{\text{skewness}} = -4.49$; hearing: $z_{\text{skewness}} = -3.34$), and are not therefore normally distributed (deaf: Shapiro Wilk statistic = .773, d.f. = 41, $p < .001$; hearing: Shapiro Wilk statistic = .858, d.f. = 41, $p < .001$; combined: Shapiro Wilk statistic = .820, df=82, $p < .001$). The distributions are illustrated in Figure M.4.

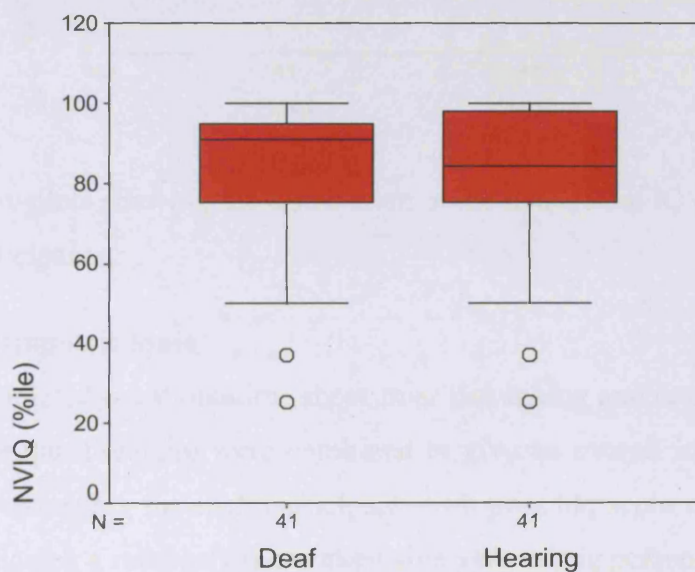


Figure M.4: Box plots showing the distribution of the non-verbal IQ data for the deaf and hearing participants

A logarithmic (to base 10) transformation of the reflected percentile data removed the significant negative skew for the both groups (deaf: $z_{\text{skewness}} = -0.025$; hearing: $z_{\text{skewness}} = -0.92$), and produced a normal distribution for the deaf group (Shapiro Wilk statistic = .957, df=41, $p = .123$). The distribution of the data for the hearing group and for the two groups combined, however, remained significantly different from normal (hearing: Shapiro Wilk statistic = .929, df=41, $p < .02$; combined: combined: Shapiro Wilk statistic = .959, df=82, $p < .02$). The transformed distributions are illustrated in Figure M.5.

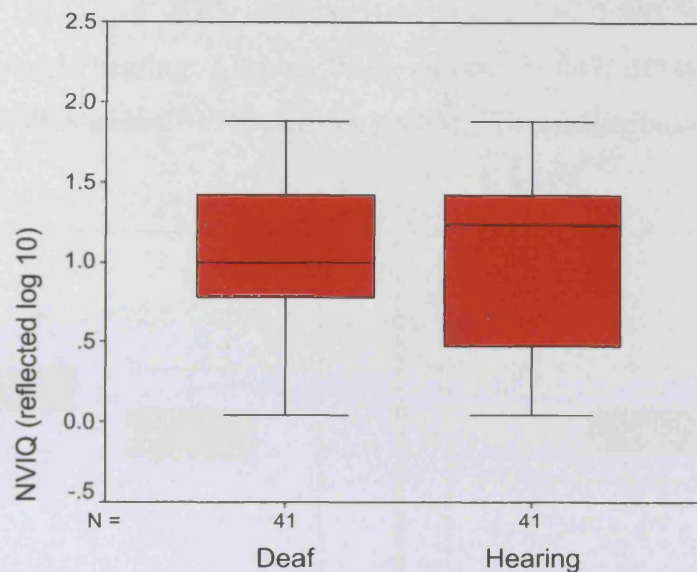


Figure M.5: Box plots showing the distribution of the non-verbal IQ data for the deaf and hearing participants

Risk-taking & Impulsiveness

Participants completed questionnaires about their risk-taking and impulsiveness. The two parts of the questionnaire were combined to give an overall indication of risk-taking and impulsiveness for each participant, with possible score range of 0 to 62. High scores indicated a relatively more impulsive, risk-taking person, and low scores, a relatively more controlled, cautious person.

These data were normally distributed for both the deaf and hearing groups (deaf: Shapiro Wilk statistic = .970, $df=20$, $p=.754$; hearing: Shapiro Wilk statistic = .974, $df=18$, $p=.869$; combined: Shapiro Wilk statistic = .983, $df=38$, $p=.833$). The raw scores were used in the analyses and did not require any pre-analysis treatment.

Minimal pairs subtest

The minimal pairs subtest consisted of ten word initial (WI), ten word medial (WM) and ten word final (WF) items, that is, targets that differed from their distracters in these word positions respectively.

The minimal pairs subtest raw score data were normally distributed for both the deaf and HoH groups (deaf: Shapiro Wilk statistic = .965, $df=41$, $p=.237$; HoH: Shapiro Wilk statistic = .956, $df=39$, $p=.131$). However, for the hearing group as a whole, and for the groups combined, these data were significantly negatively skewed (hearing

(HoH & HoD): $z_{\text{skewness}} = -2.03$; deaf & HoH: $z_{\text{skewness}} = -1.96$), and not therefore normally distributed (hearing: Shapiro Wilk statistic = .947, $df=49$, $p<.05$, deaf & HoH: Shapiro Wilk statistic = .965, $df=80$, $p<.05$). These distributions are shown in Figure M.6.

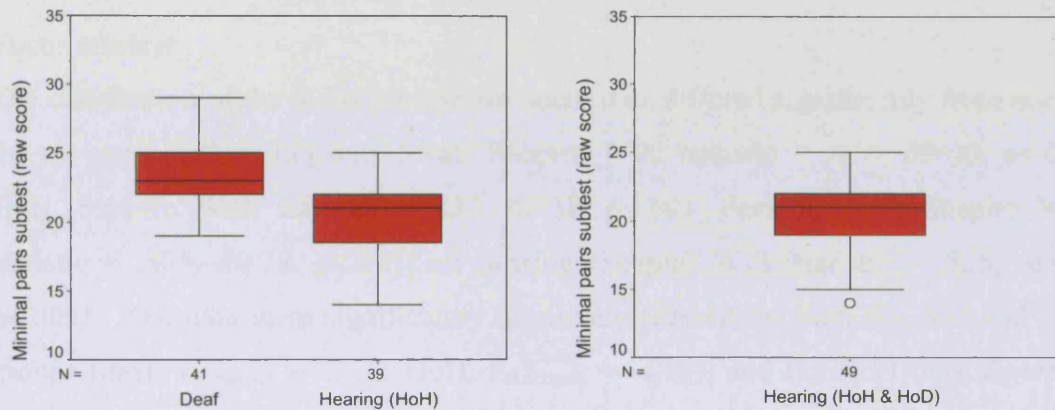


Figure M.6: Box plots showing the distribution of the minimal pairs raw score data for the deaf and HoH (left), and all hearing (right) participants

Transforming the data by reflecting it and determining its square root ($\sqrt{31-\text{minpairs}}$) improved the distribution of the HoH group's data (Shapiro Wilk statistic = .969, $df=39$, $p=.347$), and normalised the data of the deaf & HoH groups combined (Shapiro Wilk statistic = .976, $df=80$, $p=.128$) and of hearing group as a whole, removing the negative skew (Shapiro Wilk statistic = .965, $df=49$, $p=.145$; $z_{\text{skewness}} = 1.08$). The transformed distribution for the hearing participants is illustrated in Figure M.7.

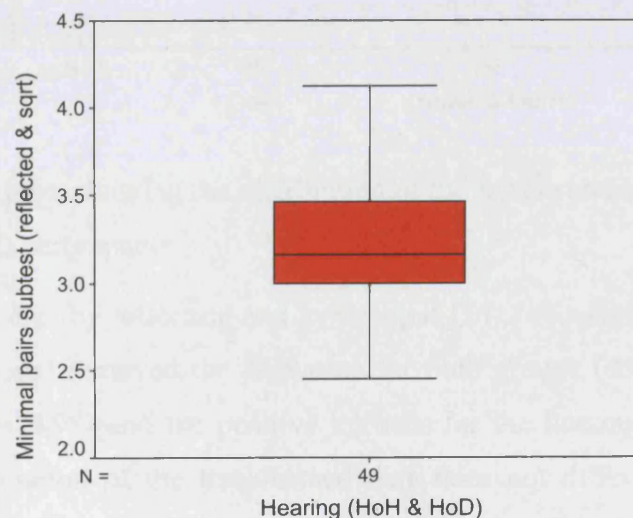


Figure M.7: Box plot showing the distribution of the transformed minimal pairs subtest data for the hearing participants

This transformation, however, created a significant negative skew in the deaf group's data ($z_{\text{skewness}} = -2.44$), making the distribution significantly different from normal (Shapiro Wilk statistic = .934, $df=41$, $p<.02$). The raw data are therefore used for analyses involving the deaf participants alone, and the transformed data otherwise.

Focus subtest

The distribution of the focus subtest raw score data differed significantly from normal for all groups of participants (deaf: Shapiro Wilk statistic = .910, $df=40$, $p<.005$; HoH: Shapiro Wilk statistic = .837, $df=38$, $p<.001$; deaf & HoH: Shapiro Wilk statistic = .885, $df=78$, $p<.001$; all hearing: Shapiro Wilk statistic = .825, $df=48$, $p<.001$). The data were significantly negatively skewed for both the deaf and HoH groups (deaf: $z_{\text{skewness}} = -2.22$; HoH: $z_{\text{skewness}} = -4.12$), and the HoH data showed a positive kurtosis of borderline significance ($z_{\text{kurtosis}} = 1.95$). These distributions are illustrated in Figure M.8.

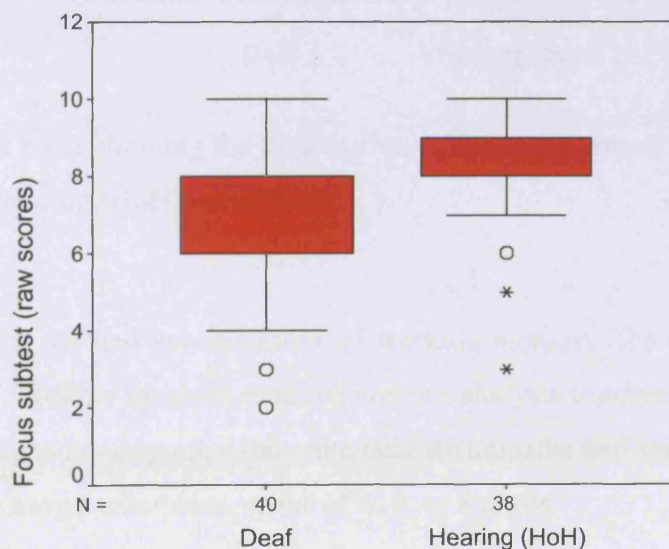


Figure M.8: Box plots showing the distribution of the focus subtest data for the deaf and hearing (HoH) participants

Transforming the data by reflecting and inverting it ($1/(17-\text{focus})$) reduced the outliers (see Figure M.9) and removed the skewness for both groups (deaf: $z_{\text{skewness}} = 0.08$; hearing: $z_{\text{skewness}} = 0.98$) and the positive kurtosis for the hearing group ($z_{\text{kurtosis}} = -0.55$). The distribution of the transformed data does not differ significantly from normal for the deaf group (Shapiro Wilk statistic = .951, $df=40$, $p=.083$), but continues to differ significantly for the HoH participants (Shapiro Wilk statistic =

.910, $df=38$, $p<.01$), and for the combined groups (deaf & HoH: Shapiro Wilk statistic = .939, $df=78$, $p<.002$; all hearing: Shapiro Wilk statistic = .900, $df=48$, $p<.002$). The transformed data will therefore be used for analyses within the deaf group. Analyses involving hearing participants will be conducted non-parametrically.

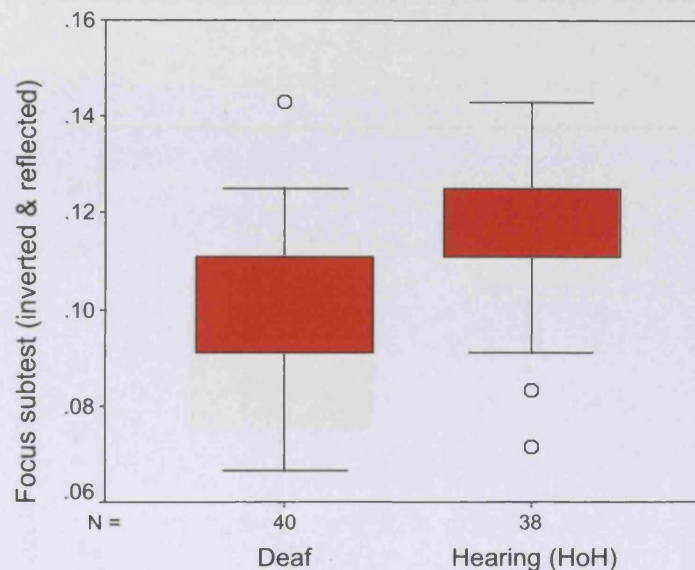


Figure M.9: Box plots showing the distribution of the transformed focus subtest data for the deaf and hearing (HoH) participants

Digit Span

The digit span task yielded two measures of working memory: the raw score and the number of digits. Neither measure required any pre-analysis treatment.

The number of digits is categorical data: the deaf participants had spans of 4, 5, 6, or 7 digits, and the hearing participants, spans of 6, 7, or 8 digits.

The raw score data were normally distributed for all groups (deaf: Shapiro Wilk statistic = .953, $df=21$, $p=.390$; hearing (HoH & HoD): Shapiro Wilk statistic = .932, $df=16$, $p=.259$; combined: Shapiro Wilk statistic = .946, $df=30$, $p=.133$). However, only 9 HoH participants completed this task. Because of the small number of participants, they will be combined with the HoD group for analysis of this variable wherever possible.

Vocabulary

The vocabulary data were significantly negatively skewed ($z_{\text{skewness}} = -3.11$), and not therefore normally distributed for the HoH group (Shapiro Wilk statistic = .858,

df=40, $p<.001$). The negative skew and difference from normal distribution were not, however, significant for the deaf group ($z_{\text{skewness}} = -1.21$; Shapiro Wilk statistic = .954, df=41, $p=.099$). These distributions are shown in Figure M.10. Attempts at transforming the vocabulary data did not remove the significant skew in the hearing group's data; non-parametric statistics will therefore be used for analyses within this group.

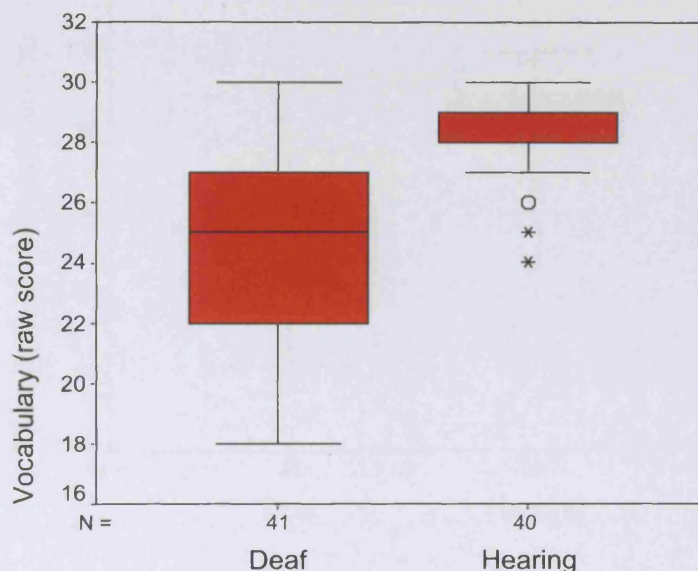


Figure M.10: Box plots showing the distribution of the vocabulary data for the deaf and hearing participants

Phonological Awareness

Each participant's phonological awareness score was the mean percentage accuracy score of the three phonological awareness tasks. These data were normally distributed, with a slight (non-significant) positive skew for the deaf group (Shapiro Wilk statistic = .957, df=41, $p=.127$; $z_{\text{skewness}} = 0.90$). For the hearing group, however, the data were significantly negatively skewed ($z_{\text{skewness}} = -2.57$). The distribution differed significantly from normal for the hearing group and for the two groups combined (hearing: Shapiro Wilk statistic = .904, df=39, $p<.005$; combined: Shapiro Wilk statistic = .942, df=80, $p<.002$). The distributions are shown in Figure M.11.

Transforming the data by reflecting and square rooting it ($\sqrt{101-PA}$) normalised the hearing data, and corrected the negative skew (Shapiro Wilk statistic = .968, df=39, $p=.314$; $z_{\text{skewness}} = 0.91$). This transformation, however, created a significant negative skew in the deaf group's data ($z_{\text{skewness}} = -2.03$), and a distribution that was

significantly different from normal (Shapiro Wilk statistic = .936, $df=41$, $p<.05$). The distribution of the data for the two groups combined also differed significantly from normal (Shapiro Wilk statistic = .930, $df=80$, $p<.02$). These transformed distributions are illustrated in Figure M.12. The raw data were therefore used in the majority of the analyses, and the transformed data only for analyses within the hearing group.

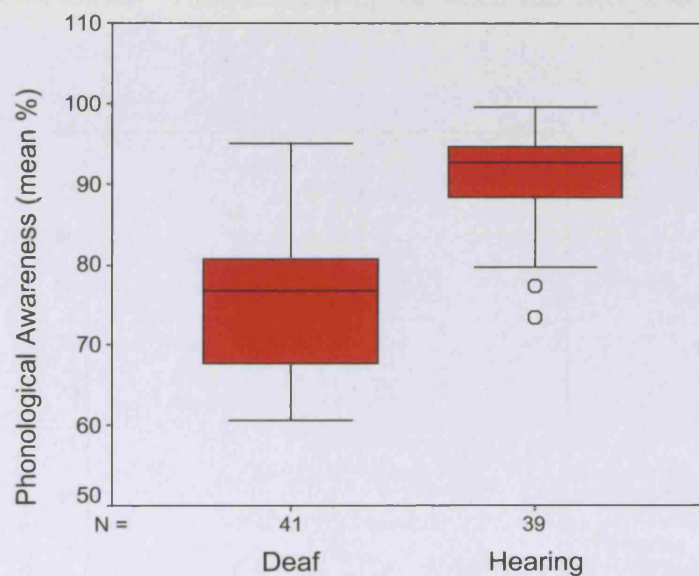


Figure M.11: Box plots showing the distribution of the phonological awareness data for the deaf and hearing participants

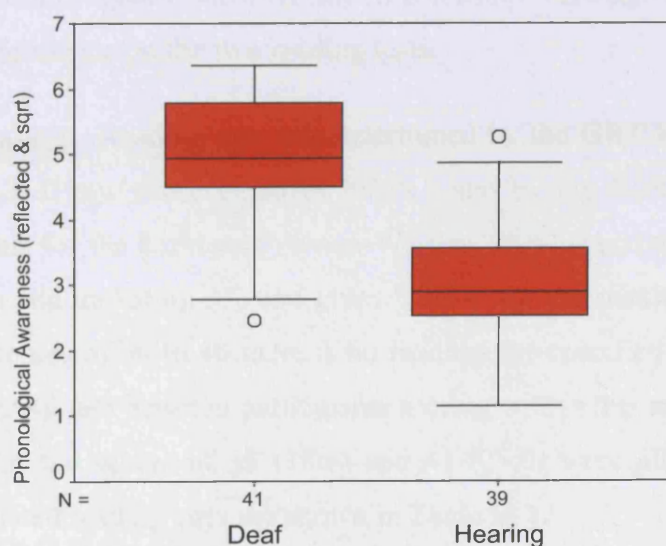


Figure M.12: Box plots showing the distribution of the transformed phonological awareness data for the deaf and hearing participants

Reading

Forty-four adults³⁸ (22 deaf, and 22 hearing), aged 19;8 to 58;11 (mean 34;4) completed both the Group Reading Test (GRT II) and the Kinklees Reading Assessment Schedule (Kinklees). The strong correlation between their raw scores on the two tests (Spearman's ρ ³⁹ = .704, $n=44$, $p<.001$) indicated that they were assessing the same skill. The relationship between the two tests is illustrated in Figure M.13.

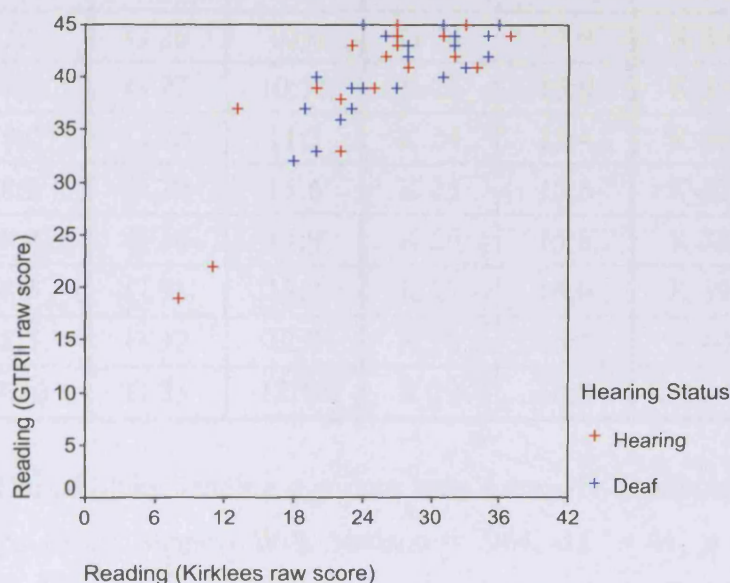


Figure M.13: Scatter graph showing the relationship between deaf and hearing participants' performance on the two reading tests.

Reading age measure: Reading age was determined by the GRT II for reading ages below 15;0 (GRT II raw score of 38 or below), and by the Kinklees for 15;0 and above. The norms for the Kinklees (Vernon-Warden 1996) specifies reading ages for raw scores up to and including 33, and gives '23;0+' for the maximum scores of 41 and 42, but for scores of 34 to 40 there is no reading age specified (they are denoted 'adult'). To discriminate between participants scoring within this range, reading ages between those for the scores of 33 (18;6) and 41 (23;0) were allocated. The raw scores and associated reading ages are shown in Table M.1.

³⁸ 29 of these adults (19 deaf and 10 hearing) were participants included in the main analyses, the other 15 (3 deaf and 12 hearing) were adults of mixed reading ability who completed only the reading tests.

³⁹ This correlation was analysed non-parametrically because the reading test raw score data were not normally distributed (GRT II: Shapiro Wilk statistic = .751, d.f.=44, $p<.001$; Kinklees: Shapiro Wilk statistic = .946, d.f.=44, $p<.05$)

Table M.1: The reading test raw scores (G – GRT II scores; K – Kirklees scores) and equivalent reading ages.

Raw score	RA	Raw score	RA	Raw score	RA	Raw score	RA
G 10	6;8	G 22	9;1	G 34	13;2	K 30	17;0
G 11	6;10	G 23	9;6	G 35	13;6	K 31	17;8
G 12	7;0	G 24	9;10	G 36	13;11	K 32	18;4
G 13	7;2	G 25	10;2	G 37	14;4	K 33	18;6
G 14	7;5	G 26	10;6	G 38	14;9	K 34	19;0
G 15	7;8	G 27	10;11	K 23	15;0	K 35	19;6
G 16	8;0	G 28	11;3	K 24	15;4	K 36	20;0
G 17	8;2	G 29	11;6	K 25	15;6	K 37	20;6
G 18	8;4	G 30	11;9	K 26	15;8	K 38	21;0
G 19	8;5	G 31	12;2	K 27	16;0	K 39	21;6
G 20	8;7	G 32	12;7	K 28	16;4	K 40	22;0
G 21	8;10	G 33	12;10	K 29	16;8	K 41-42	23;0

Distribution: The resultant reading age data were normally distributed for the deaf and HoH groups (deaf: Shapiro Wilk statistic = .964, d.f. = 41, $p = .212$; HoH: Shapiro Wilk statistic = .946, d.f. = 40, $p = .055$). However, the distribution differed significantly from normal for the two groups combined (Shapiro Wilk statistic = .968, d.f. = 81, $p < .05$). These distributions are illustrated in Figure M.14.

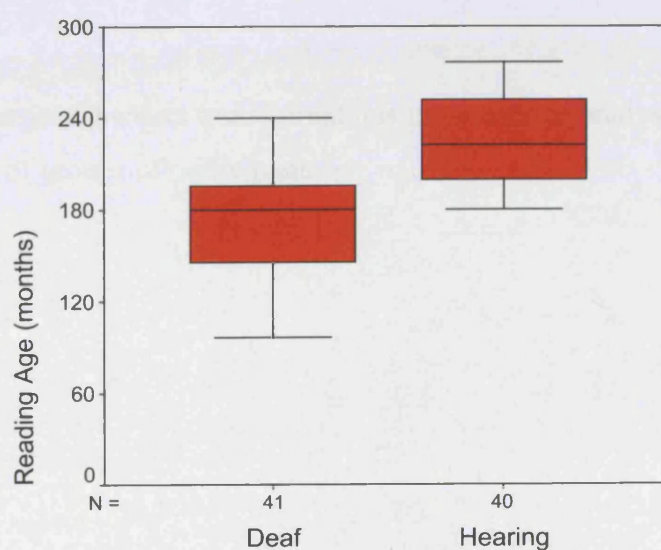


Figure M.14: Box plots showing the distribution of the reading age data for the deaf and hearing participants

Transforming the data by reflecting it and taking the square root ($\sqrt{(400 - RA)}$) produced distributions that did not significantly differ from normal for the combined data as well as for the two groups (deaf: Shapiro Wilk statistic = .965, d.f. = 41, $p = .241$; hearing: Shapiro Wilk statistic = .945, d.f. = 40, $p = .052$; combined: Shapiro Wilk statistic = .972, d.f. = 81, $p = .072$). The transformed distributions are illustrated in Figure M.15. The raw reading age data will be used in intra-group analyses, and the transformed data in inter-group analyses.

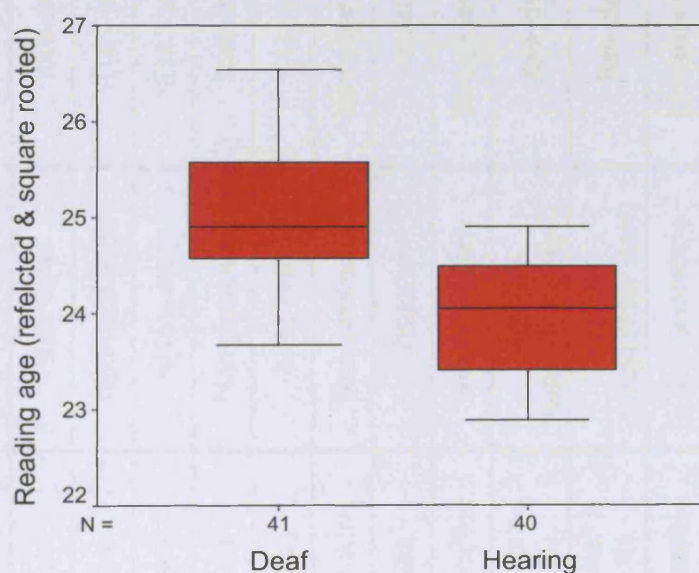


Figure M.15: Box plots showing the distribution of the transformed reading age data for the deaf and hearing participants

Summary

Table M.2 summarises the data transformations to be used in analyses for each group, and combination of groups of participants.

Table M.2: Summary of data used in analyses

Transformations are specified, and 'Non-parametric' indicates where transformations did not result in normal distributions

	Deaf	HoH	Deaf & HoH	Hearing (HoH & HoD)	All participants (Deaf, HoH & HoD)
TAS core subtests	Raw data	Raw data	Raw data	Raw data	Raw data
TAS words subtest	Non-parametric	Raw data	Non-parametric	$\sqrt{(16 - \text{raw})}$	Non-parametric
TAS sentences subtest	$\sqrt{(16 - \text{raw})}$	Raw data	$\sqrt{(16 - \text{raw})}$	$\sqrt{(16 - \text{raw})}$	$\sqrt{(16 - \text{raw})}$
TAS stories subtest	Non-parametric	Raw data	Non-parametric	Raw data	Non-parametric
Minimal pairs subtest	Raw data	$\sqrt{(31 - \text{raw})}$	$\sqrt{(31 - \text{raw})}$	$\sqrt{(31 - \text{raw})}$	$\sqrt{(31 - \text{raw})}$
Focus subtest	1/(17-row)	Non-parametric	Non-parametric	Non-parametric	Non-parametric
Age	1/months	1/months	1/months	1/months	1/months
NVIQ	$\lg_{10}(101 - \text{ile})$	Non-parametric	Non-parametric	Non-parametric	Non-parametric
Risk-taking & impulsiveness	Raw data	Raw data (small N)	Raw data (small N for HoH)	Raw data	Raw data
Digit span	Raw data	Non-parametric (small N)	Raw data (small N for HoH)	Raw data	Raw data
Vocabulary	$\sqrt{(31 - \text{raw})}$	Non-parametric	Non-parametric	Non-parametric	Non-parametric
Phonological Awareness	Raw scores	$\sqrt{(101 - \text{raw})}$	Non-parametric	$\sqrt{(101 - \text{raw})}$	Non-parametric
Reading	RA	RA	$\sqrt{(400 - \text{RA})}$	Non-parametric	Non-parametric
Motion Coherence Threshold	\lg_{10}	Raw scores	\lg_{10}	Raw scores	\lg_{10}
Form Coherence Threshold	Raw scores	Raw scores	Raw scores	Raw scores	Raw scores

APPENDIX N:

Investigation of speechreading skills and the speechreading-reading relationship in adults diagnosed with dyslexia

Introduction

Adults diagnosed as dyslexic typically struggle to reach reading levels commensurate with their age and intellectual skills, as do deaf adults. In addition, they are often described as having had problems in the acquisition of spoken language. Their difficulties are believed to stem from impairments in the central processing of speech and language, which may be conceptualised as psycholinguistic or perceptual in nature. The exact nature of these, however, has been the subject of much research and debate, and will be touched on only very briefly here. From a psycholinguistic perspective, the prevalent view is that people who have difficulties in learning to read have problems in establishing and maintaining adequate phonological representations (e.g. Vellutino et al. 1995). From a perceptual perspective, the difficulty is seen to be more general, in the visual domain (e.g. Stein 2003), and/or the auditory domain (e.g. Tallal 1980).

Very little is known about speechreading in dyslexics. In one study (de Gelder & Vroomen 1998), audiovisual speech integration was found to be deficient in poorer readers compared with good readers. In another (Campbell et al. 1997), dyslexic individuals were found to be less good at distinguishing syllables such as 'ba', 'tha', 'va' or 'da' when they were presented either auditorially or visually, although they reached normal levels of report when the syllables were presented audiovisually. There are suggestions, then, that the speechreading skills of adults who have been diagnosed with dyslexia may be poorer than those of non-dyslexic adults. If this is the case, using the subtests of the TAS may allow the loci of their speechreading deficit to be investigated. It is also possible that speechreading will be related to other language skills in dyslexic adults. The relationship between speechreading and reading, and the factors that may underlie it, are of particular interest.

The following questions are addressed in this study:

- 1 Do the speechreading abilities of hearing adults who have been diagnosed with dyslexia differ from those of non-dyslexic hearing adults?
- 2 Is speechreading related to other language skills (vocabulary and phonological awareness) in adults who have been diagnosed with dyslexia?
- 3 Is there a significant relationship between speechreading and reading in hearing adults who have been diagnosed with dyslexia?
- 4 If so, do the speechreading-reading relationships in deaf adults and in hearing adults who have been diagnosed with dyslexia reflect the same variables?

Methods

Participants

Twenty-six normally hearing adults who had been diagnosed with dyslexia were recruited for this study. The participants were volunteers, and had English as a first spoken language. Their non-verbal IQ, tested using the block design task from the Weschler Adult Intelligence Scale–Revised (WAIS–R, Wechsler 1981), was within 2 SD of the mean, and they had normal or corrected-to-normal vision and no additional disabilities. The majority (86%) were undertaking or had completed tertiary education. They had been diagnosed as dyslexic by an educational or clinical psychologist.

Each dyslexic participant was matched as far as possible with a hearing (HoH) adult and a deaf adult from the main study. The triplets of dyslexic, hearing and deaf participants were matched as far as possible on age, gender, non-verbal IQ, regional spoken accent, and level of education. The demographic characteristics of the matched groups are summarized in Table N.1.

Materials

The dyslexic participants completed the same test battery (excluding the motion and form coherence tasks, which were unavailable due to technical difficulties), following the same procedures, as had the participants in the main study (see section 9.2).

Table N.1. The means and standard deviations of the matched groups' ages and non-verbal IQ's, and the numbers of participants in each group categorized by gender, education level and regional spoken accent

	Dyslexic		Hearing (HoH)		Deaf	
	Mean	S.D.	Mean	S.D.	Mean	S.D.
Age (yrs;mths)	25;9	5.96	27;11	7.29	30;2	5.22
Non-verbal IQ (%ile)	77.7	17.77	84.1	17.12	84.0	15.63
	N	%	N	%	N	%
Gender (male)	13	50.0%	12	46.2%	11	42.3%
Education level (tertiary educated)	22	84.6%	22	84.6%	17	65.4%
Regional accent (similar to talkers)	21	80.8%	16	61%	17	65.4%

Results

Comparison of dyslexic and non-dyslexic adults' speechreading abilities

The speechreading performance of the three groups is illustrated in Figure N.1.

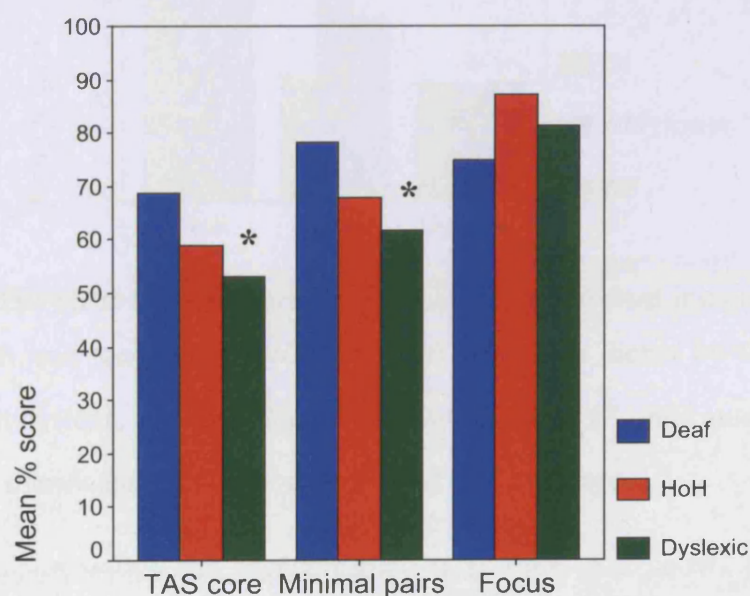


Figure N.1: Bar chart showing mean performance on the TAS core subtests by the matched dyslexic, non-dyslexic hearing (HoH) and deaf groups (* indicates a dyslexic performance significantly different from that of the HoH group)

The dyslexic adults speechread significantly less well than the matched HoH group on the core subtests ($t(50)=2.11$, 2-tailed $p<.05$) and on the minimal pairs task ($t(49)=2.32$, 2-tailed $p<.05$). Their performance on the focus task fell between that of the HoH and deaf groups, but was not significantly different from either.

Performance on the WI, WM & WF minimal pairs items: Figure N.2 illustrates the groups' performance on the minimal pairs items grouped by word position. It can be seen that the reduced deaf and HoH groups showed the same patterns as the larger groups included in the main thesis study (see Figure 7.7, pg. 227). The dyslexic group, however, showed a markedly different pattern: their performance did not differ as a function of the word position of the discriminatory phoneme.

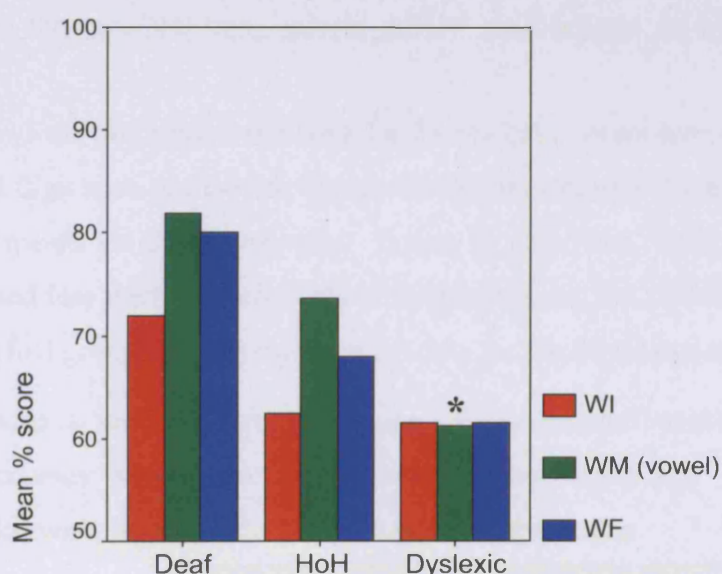





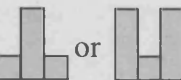


Figure N.2: Bar chart showing mean performance on the word initial (WI), word medial (WM) and word final (WF) minimal pairs task items by the matched dyslexic, non-dyslexic hearing (HoH) and deaf groups (* indicates a dyslexic performance significantly different from that of the HoH group)

Profiles of scores within the speechreading test: Table N.2 shows the dyslexic participants' profiles of scores on the TAS core subtests (see pg. 202 for descriptions of the profiles). The results for the deaf, HoH and HoD groups (from section 6.10) are repeated here for comparison. It can be seen that a relatively high proportion of the dyslexic group have been categorised in profile 5. This contrasts particularly markedly with the HoD group.

Table N.2: Crosstabulation of the profiles of scores on the TAS core subtests for the deaf, HoH and HoD groups

	1. Good	2. Flat	3. Expected	4. Stories ↓	5. Words ↑	6. Odd
						
Dyslexic	0	1 (4.5%)	7 (32%)	7 (32%)	6 (27%)	1 (4.5%)
Deaf	17%	0	17%	56%	10%	0
HoH	0	5%	29%	49%	12%	5%
HoD	0	20%	10%	70%	0	0

Comparison of dyslexic and non-dyslexic adults' performance on other language measures

Table N.3 shows the descriptive statistics for the reading, vocabulary, phonological awareness and digit span tasks, with the results of comparisons of the dyslexic and HoH groups' means on these measures. It can be seen that, while the dyslexic group performed less well on each of these language tasks, the difference between them and the HoH group reached significance only for the digit span task.

Table N.3: Means and standard deviations of the groups' reading ages and percentage accuracy scores for the expressive vocabulary and phonological awareness tasks, with the results of t-tests comparing the means

	Dyslexic		HoH (Non-Dyslexic)		Significant Difference?
	Mean	(S.D.)	Mean	(S.D.)	
Reading age (months)	217.38	(34.46)	226.15	(28.21)	NS
Vocabulary (% correct)	94.10	(6.13)	94.58	(4.87)	NS
PA (% correct)	88.33	(7.72)	90.10	(6.88)	NS
Digit Span (raw score)	21.53	(3.36)	26.40	(3.38)	$p < .05$

Correlations between speechreading, reading, phonological awareness and vocabulary

Performance on the core TAS sub-tests, reading and phonological awareness inter-correlated (all at $p < .05$ or greater; see Table N.4). The correlation between speechreading and phonological awareness survived controlling for vocabulary

($r=.416$, $d.f.=23$, $p<.05$), but the correlation with vocabulary did not reach significance when phonological awareness was controlled for ($r=-.255$, $d.f.=23$, $p=.218$). The correlation between speechreading and reading did not reach significance when either vocabulary ($r=.154$, $d.f.=23$, $p=.463$) or phonological awareness ($r=-.026$, $d.f.=23$, $p=.904$) was controlled for.

Table N.4: Inter-correlations between speechreading, reading, phonological awareness and vocabulary for the dyslexic participants

		Reading Age	Phonological Awareness	Vocabulary
TAS	<i>r</i>	.376	.473	.417
	<i>p</i>	.042	.013	.027
Phonological Awareness	<i>r</i>	.702	--	.396
	<i>p</i>	.000	--	.034
Vocabulary	<i>r</i>	.496	.396	--
	<i>p</i>	.009	.034	--

Discussion

Do the speechreading abilities of hearing adults who have been diagnosed with dyslexia differ from those of non-dyslexic hearing adults?

Hearing participants with a history of dyslexia were poorer speechreaders than their hearing peers, although their reading skills had become equivalent to those of the hearing controls. The dyslexic group's profile of performance on the minimal pairs items suggests that their ability to identify the segmental constituents of words by eye is poor. Their performance on the WM (vowel) items was particularly poor in comparison to that of the hearing or deaf participants. Their profiles of performance on the core subsets further suggest that they may be less able to segment and identify words in a longer speech stream. Adults with a history of dyslexia may be more dependent on bottom-up processing, reflecting their experience with audiovisual segmental speech structure, and may be restricted by their limited ability to identify the segmental constituents of words by eye.

Is speechreading related to other language skills (vocabulary and phonological awareness) in adults who have been diagnosed with dyslexia?

Speechreading performance on the TAS correlated significantly with both expressive vocabulary score and phonological awareness score for the dyslexic group, as they did for the deaf group (see section 9.4.i). This suggests that language abilities can limit speechreading abilities in hearing adults when there is a history of literacy difficulties and language skills are less well developed they might otherwise be (even when the differences are not great enough to be significant when measured with the tasks included here). The results of the partial correlations, however, suggest that the limiting language factor differs in deaf and dyslexic groups. In the deaf group, the speechreading-vocabulary relationship survived controlling for phonological awareness, whereas the speechreading-phonological awareness correlation did not survive controlling for vocabulary (see Table 9.5, pg. 277). Regression analyses confirmed that vocabulary, but not phonological awareness made an independent contribution to the variance in speechreading performance (pg. 284). In the dyslexic group, on the other hand, partial correlations suggested the opposite: the speechreading-phonological awareness correlation survived controlling for vocabulary, but not the other way round. This supports the hypothesis that the deficit in speechreading in people with dyslexia may arise from a deficit in the adequacy of their speech-based (i.e. phonological) representations (Goswami 2003).

Is there a significant relationship between speechreading and reading in hearing adults who have been diagnosed with dyslexia?

There was no relationship between reading and speechreading in hearing non-dyslexics (see section 9.4.vi), for whom reading had become highly automated. However, reading correlated with speechreading in both of the groups with a history of reading disorder and likely phonological deficits – deaf people (see section 9.4.i) and people diagnosed with dyslexia. This does not appear to be a relationship based on level of reading or speechreading ability, since the groups differed markedly in their reading and speechreading skills: the deaf group were comparatively good speechreaders, but poor readers, whereas the dyslexic group were good readers, but poor speechreaders.

Do the speechreading-reading relationships seen in deaf adults and in hearing adults who have been diagnosed with dyslexia reflect the same variables?

In both groups, reading and speechreading were inter-correlated with phonological awareness and vocabulary. In the deaf group, regression analyses suggested that vocabulary made the greatest contribution to the speechreading-reading relationship. Phonological awareness did play a role, but reading accounted for further variance in speechreading performance after that accounted for by phonological awareness (see pg. 286-287). In the dyslexic group, however, the speechreading-reading relationship did not survive when phonological awareness was partialled out, suggesting that the relationship in this group may be mediated to a greater extent by speech-based (phonological) representations. The inter-correlation with vocabulary suggests, however, that the best determinants of individual differences in both reading and speechreading relate to language knowledge as well as to phonological knowledge.

It should be noted that the majority of the dyslexic individuals included here were university students, and as such form a high functioning, compensated, and therefore unrepresentative sample. Further research with a more representative sample of dyslexic adult participants is needed to establish whether the findings presented here apply to dyslexic adults generally. The prediction would be that, since the participants included here had relatively good language skills, the poorer skills expected in a more representative dyslexic group would limit their speechreading skills further, resulting in similar, but stronger, correlations to those seen here.

An additional area of interest, and of future research, concerns motion coherence sensitivity. The preliminary findings with deaf and non-dyslexic hearing adults suggest that motion coherence sensitivity plays a role in speechreading for deaf and hearing adults (see Chapter 8), and in reading for deaf adults, whose reading skills are limited and not fully automatic (see section 9.4.iii). There have also been a number of studies showing that some adults with developmental dyslexia are less sensitive than control subjects at detecting coherent motion (e.g. Hansen et al. 2001; Talcott et al. 2000; Witton et al. 1998). It will be interesting to see whether motion coherence sensitivity is related to reading in dyslexic adults as it is in deaf

adults. The former may have elevated motion coherence thresholds and would be expected to have depressed reading skills. The latter also show depressed reading skills, but demonstrate motion coherence thresholds that do not differ from those of hearing adults (and have been found to have specific magnocellular enhancements, e.g. Armstrong et al. 2002; Bavelier et al. 2000; 2001; Neville & Lawson 1987a; see section 8.3). A further, related, question is whether motion coherence sensitivity has a role in the relationship between speechreading and reading in dyslexic individuals.

APPENDIX O: Extended Abstract

Speechreading is the major route through which deaf people access the spoken language of the society in which they live. However, speech is not the chosen primary mode of communication for many deaf people, and there has been considerable disagreement in the literature over the respective speechreading abilities of hearing and deaf people. This thesis investigates speechreading and its correlates in a group of profoundly congenitally deaf British adults, and in a control group of hearing adults. For this purpose, the Test of Adult Speechreading (TAS) was developed.

Chapter 1 provides an introduction to speechreading and to the thesis. The term ‘speechreading’ is defined, and its role in the communication of hearing and d/Deaf adults discussed. The specific aims of the current study are then described. The two chapters that follow present background literature reviews on deafness and on speech processing.

Chapter 2 constitutes an introduction to deafness. The terms that are important in research involving deaf participants are defined, factors that contribute to the heterogeneity of the deaf population are outlined, and factors likely to affect the speechreading abilities and strategies of the deaf participants in this thesis are discussed. A number of factors are identified for investigation in later chapters as having the potential to affect the speechreading abilities and strategies of the deaf participants in the thesis. These include cause and age at diagnosis of deafness, hearing aid use, tinnitus, communication mode experience and preference, type of school, and parental hearing status. In addition, this chapter considers the differences in the development of spoken language in congenitally deaf and hearing children, and the impact that these have on their respective speech processing abilities in adulthood. The spoken language of deaf individuals differs from that of hearing individuals throughout development, from the earliest stages in infancy. The effects of these differences are pervasive and likely to have an enormous impact on the spoken language processes and representations of deaf adults.

In **Chapter 3**, the focus shifts to adult speech processing. This chapter provides an overview of the processes involved in decoding and understanding spoken English, focussing on speech processing in profoundly congenitally deaf adults and when only

visual information is available. Specifically, it addresses questions related to segmenting the speech stream, the visibility of speech at the segmental level, the importance of different aspects of the speech signal, the ‘objects of perception’ for speech, normalization, working memory, phonological coding, and top-down processing.

The subsequent two chapters describe the development of the speechreading assessment used in this thesis, the new Test of Adult Speechreading (TAS). This test was required to assess speechreading at different linguistic levels, to be suitable for use with both congenitally deaf and hearing adults’ speechreading skills, and to investigate the relationship between reading and speechreading. Initially, **Chapter 4** reviews extant speechreading assessments with the aim of establishing what the new speechreading assessment should comprise. This is followed by a description of the development and piloting of the initial, video version of the TAS, and preliminary reliability and validity investigations. The initial version of the test comprised 3 subsections: single words, sentences, and connected speech (short stories). It was found to have high reliability and validity, and to be a potentially useful measure of speechreading ability that therefore warranted further development.

Chapter 5 presents the further development and digitisation of the TAS. Modifications to the three subtests were made following item analysis of the video version of the test. The modified test was then piloted, filmed and digitised. Following the description of these stages of test development, the test properties are investigated, including reliability, validity and item analysis. The resultant test is a speechreading assessment that is sensitive to the perceptual abilities that underlie speechreading at different linguistic levels. The vocabulary and syntax used were selected to be familiar to Deaf adults, and the response mode, using picture choices only, makes no demands on written or expressive spoken English. The TAS is appropriate, therefore, for use with d/Deaf as well as hearing individuals.

The four chapters that follow investigate different aspects of speechreading. **Chapter 6** investigates speechreading performance on the TAS as a function of variables related to the speechreader. Following a review of the relevant literature, the speechreading performance of the deaf and hearing groups are considered with respect to their hearing status, and also to other demographic variables, including their parental hearing status, gender, age, intelligence, and personality, and deaf-specific variables such as hearing aid use and language experience and preference.

Adults who were born profoundly deaf were found to perform significantly better than hearing adults on the TAS. This finding corroborates and extends previous findings that carefully selected oral deaf college students can speechread better than hearing students, since the deaf participants were not selected on the basis of their educational or language experiences and preferences. In fact the majority of these participants identified British Sign Language (BSL) as their preferred language.

The results further suggest that, for these deaf adults, hearing aid use, the language approach used at home during childhood, and a personality factor (risk-taking & impulsiveness) have independent effects on speechreading performance. There is no evidence of any impact of BSL experience or use on speechreading ability in this study. The deaf participants were found to be more accurate at rating their own speechreading ability, and showed evidence of being more able than their hearing peers to segment the visually perceived speech stream, and to make use of factors such as syllable number that facilitate speechreading.

To further elucidate the different speechreading abilities of deaf and hearing adults, their performance on two additional speechreading tasks are considered in **Chapter 7**. Initially, the development of the additional tasks is described. They were designed to assess the speechreader's ability to discriminate between minimal pairs, and to identify the focus of a speechread sentence, respectively. The groups' performance on these tasks, and the relationships between the speechreading measures are then considered.

On the minimal pairs task, the deaf participants outperformed the hearing. Considered as a group, the former, but not the latter, were able to identify which of a pair of words was spoken with above chance-level accuracy when the words differed only in one phoneme from the same visemic category (e.g. fan / van, card / cart).

On the focus task, all of the groups of participants, deaf and hearing, were able to respond with above chance-level accuracy. This was the only speechreading task on which the hearing participants outperformed those who were deaf. The hearing group's superior performance on this task is hypothesised to reflect their audiovisual experience of focus.

The next two chapters investigate further potential correlates of the participants' speechreading abilities. **Chapter 8** considers the relationship between low-level visual skills and speechreading. The results suggest that sensitivity to visual motion coherence is significantly associated with speechreading skill in both

the deaf and hearing participants. A task of form coherence with identical testing procedures and very similar parameters, on the other hand, showed no relationship with speechreading. This adds support to the hypothesis that speechreading may rely critically on information carried in the dynamic, time-varying properties of articulation.

In **Chapter 9**, the deaf and hearing participants' performance on four language-related measures (digit span, vocabulary, phonological awareness and reading), and the relationships between those measures and speechreading, are investigated. As expected, the hearing participants significantly outperformed the deaf participants on each of the language tasks. The language measures were, unsurprisingly, inter-correlated, and each correlated significantly with speechreading performance on the TAS. The correlational and regression analyses presented suggest that lexical knowledge and working memory are particularly important in speechreading for deaf British adults.

Chapter 10 investigates the characteristics and task performances of the highest- and lowest-scoring deaf speechreaders to assess the extent to which good and poor speechreaders have similar profiles, and the extent to which the factors associated with good/poor speechreading are seen consistently in these individuals. The *k*-means cluster analyses and multiple case studies presented both confirm and extend the findings of the previous chapters. The participants who achieved the highest speechreading scores all showed good vocabulary, working memory and reading skills, and also performed well on the focus task. Their performances on the other measures were more variable.

The skills and characteristics of the highest- and lowest-scoring speechreaders also illustrate the diversity of good and poor deaf speechreaders. They demonstrate that while language and lifestyle choices and experiences, personality traits, and spoken language abilities are associated with good speechreading, they are not all necessary in an individual for them to become an excellent speechreader.

Chapter 11 consists of two sections: The first considers the strengths, limitations, and future directions of the Test of Adult Speechreading (TAS). The second summarises the principal findings from the thesis, and explores the theoretical implications of these. Finally, the limitations of this research are considered, and potential future research directions proposed.

Lips are not for Reading

Stanley Rose (1970)

*I looked with longing at her lips, But how I hoped to read those lips,
To scan the words appearing. To know what she was saying;
I could not make out what she said; To guess that enigmatic smile
Alas, I have no hearing. Around the corners playing.*

*And as I gazed upon her face
It seemed I saw a pleading.
And then I knew, the words came through:
“Lips are not just for reading.”*